NOVEMBER 1957

Journal

VOL. 49 • NO. 11

AMERICAN WATER WORKS ASSOCIATION

The water's fine at Honolulu—here at Waikiki Beach or anywhere on tap

Two parts—Part 1 (AWWA Directory is Part 2):

AUTOMATIC AND REMOTE CONTROLS
McLendon, Zihal, Coffman, Schroeder

FUTURE DEVELOPMENTS IN WINNIPEG
Bubbis

HONOLULU WATER SUPPLY
Morgan

JAR TESTS
Black, Buswell, Eidsness, Black, Cohen

BICARBONATE ION IN CORROSION INHIBITION
Shuldener, Lehrman

SOLUTION EFFECTS ON CONCRETE AND CEMENT
Flentje, Sweitzer

COMPARISON OF MPN AND MF METHODS
Adams

METER-SETTING DEVELOPMENTS
Weir, Carns, Arnold, Smith, MacDonald

FLUORIDATION STATUS IN 1956
Task Group Report

DETERMINATION OF CHLORIDE ION
West, Coll

STRONTIUM IN WISCONSIN WATERS
Nichols, McNall

UNDERGROUND STORAGE RESERVOIRS
Patterson

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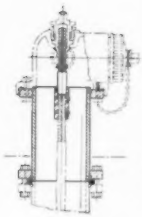
A Low-Cost Hydrant You Can Depend On

The R. D. Wood Standard Swivel Joint Hydrant gives you the most for your money in strength, reliability and sound design. The *all-bronze stuffing box*, gland and operating nut prevent rust and corrosion. Internal friction which might lower pressure is reduced to well below A.W.W.A. specifications by tapered nozzleways and carefully rounded changes in diameter.



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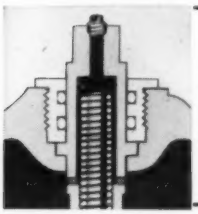

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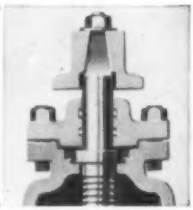

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Journal

AMERICAN WATER WORKS ASSOCIATION

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November 1957

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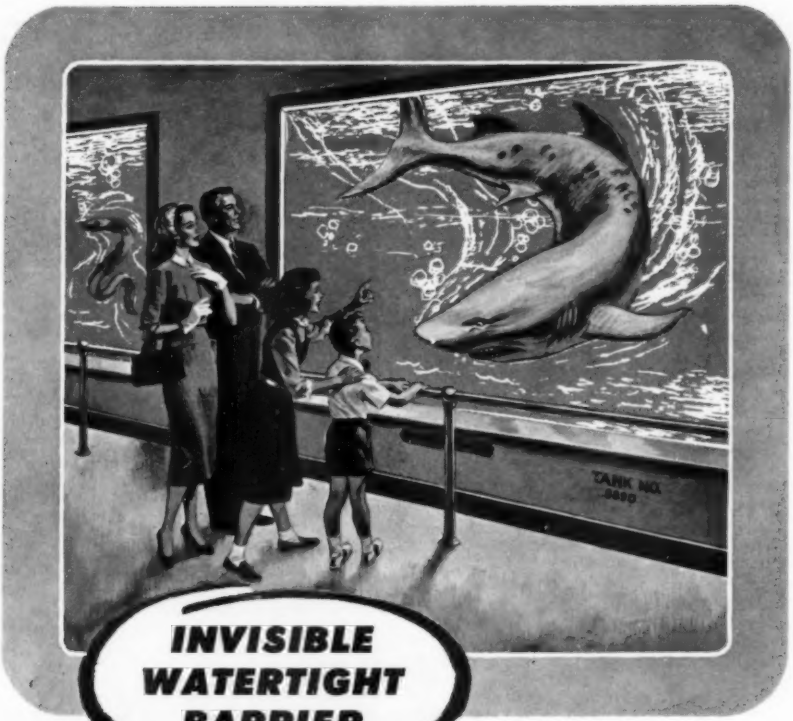

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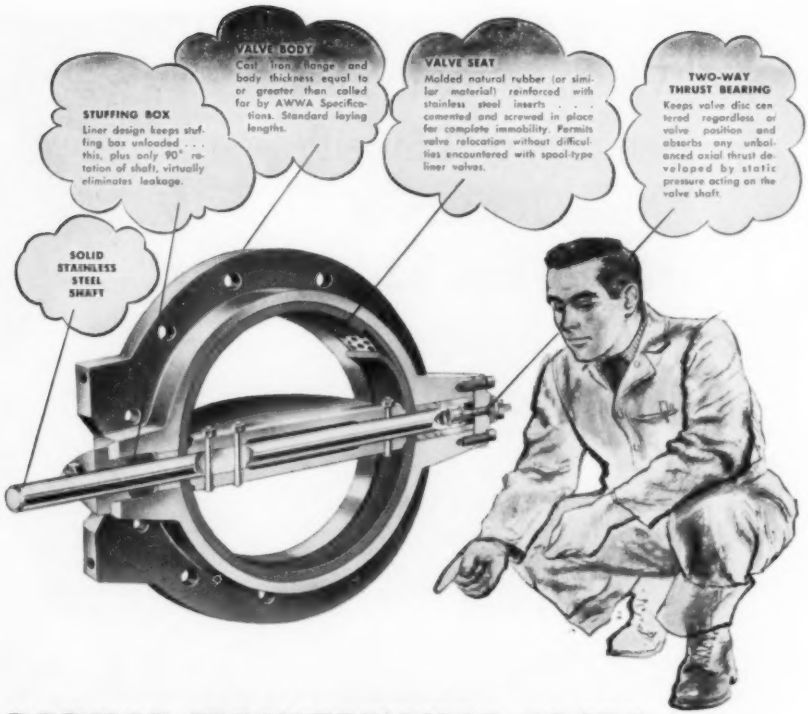
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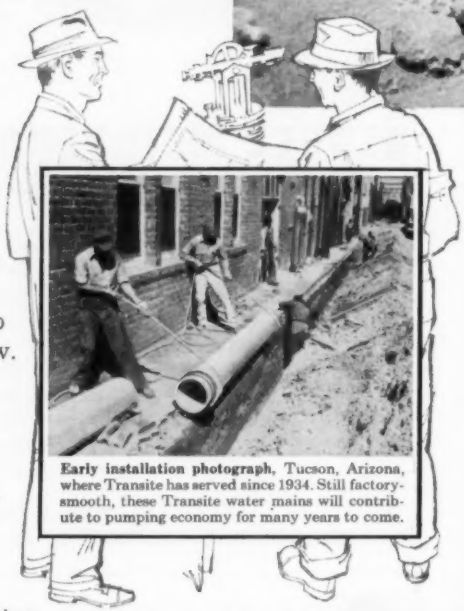

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Dallas, Tex. Apr. 20–25, 1958

Coming Meetings

AWWA SECTIONS

Fall 1957 Meetings

Nov. 10–13—Florida Section, at Roosevelt Hotel, Jacksonville. Secretary, J. D. Roth, P.O. Bin "O," Miami Beach 39.

Nov. 11–13—North Carolina Section, at Hotel Sir Walter, Raleigh. Secretary, W. E. Long Jr., State Stream Sanitation Com., Raleigh.

Nov. 14–16—Cuban Section, Havana. Secretary, C. M. Labarrere, Vice-Pres., Dussaq Co., Apdo. 278, Havana.

Spring 1958 Meetings

Jan. 28—New York Section Midwinter Luncheon Meeting, Park-Sheraton Hotel, New York. Secretary, Kimball Blanchard, Ludlow Valve Mfg. Co., Inc., 11 W. 42nd St., New York 36.

Feb. 5–7—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, C. H. Canham, 3517 Manor Court, Indianapolis.

Mar. 12–14—Kansas Section, at Lamer Hotel, Salina. Secretary, Harry W. Badley, Representative, Neptune Meter Co., 119 W. Cloud, Salina.

Mar. 20–22—Montana Section, at Florence Hotel, Missoula. Secretary, Arthur W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

Mar. 23–25—Southeastern Section, at Dinkler-Plaza Hotel, Atlanta, Ga. Secretary, N. M. deJarnette, Engr., Div. of Water Pollution Control, State Dept. of Health, 309 State Office Bldg., Atlanta, Ga.

Mar. 26–28—New York Section, at Van Curler Hotel, Schenectady. Secretary, Kimball Blanchard, Ludlow Valve Mfg. Co., Inc., 11 W. 42nd St., New York 36.

(Continued on page 10)

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cast iron pipe

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Iowa Valve Company, Oskaloosa, Iowa

Coming Meetings

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Mar. 26–28—Illinois Section, at LaSalle Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago.

Apr. 16–18—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, John E. Olsson, Cons. Engr., 408 Sharp Bldg., Lincoln.

May 15–17—Pacific Northwest Section, at Davenport Hotel, Spokane, Wash. Secretary, Fred D. Jones, Asst. Supt., Water Dept., 306 City Hall, Spokane, Wash.

May 15–17—Arizona Section, at El Conquistador Hotel, Tucson. Secretary, Stanford I. Roth, Supervisor of Water Collections, Div. of Water & Sewers, Phoenix.

Jun. 1–4—Canadian Section, at Royal York Hotel, Toronto, Ont. Secretary, A. E. Berry, Gen. Mgr. & Chief Engr., Ontario Water Resources Commission, Parliament Buildings, Toronto.

Jun. 25–27—Pennsylvania Section, at Hotel Lawrence, Erie. Secretary, L. S. Morgan, Div. Engr., State Dept. of Health, Greensburg.

OTHER ORGANIZATIONS

Nov. 11–15—Annual Meeting, American Public Health Assn., Cleveland, Ohio.

Nov. 13–15—National Conference on Standards, American Standards Assn., at St. Francis Hotel, San Francisco, Calif.

Nov. 18–21—Water Works Operators Short Course, Purdue University. For information, write: Prof. Harvey Wilke, Civil Engineering Bldg., Purdue University, West Lafayette, Ind.

Nov. 20–22—Water Works Management Short Course, University of Illinois, at Allerton Park, Monticello, Ill. For information, write: Short Course Supervisor, 116 C Illini Hall, Champaign, Ill.

Dec. 2–6—Exposition of Chemical Industries, at the Coliseum, New York, N.Y.

1953

Jan.–Mar.—Short courses sponsored by R. A. Taft Sanitary Engineering Center: Basic Radiological Health (Jan. 13–24), Environmental Health Aspects of Nuclear Reactor Operations (Jan. 27–31), New Techniques in Bacteriological Examination of Water (Jan. 27–31), Detection and Control of Radioactive Pollutants in Water (Feb. 24–28), Advanced Training for Sanitary Engineers in Water Supply and Water Pollution (Mar. 3–14), Sanitary Engineering Aspects of Nuclear Energy (Mar. 17–28). Apply to: Chief, Training, R. A. Taft Sanitary Engineering Center, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Jan. 27–31—Prestressed Concrete Short Course, Ellinor Village, Daytona Beach, Fla. Conducted by Civil Engineering Dept., University of Florida, Gainesville.

Mar. 17–21—4th EJC Nuclear Engineering & Science Conference and International Atomic Exposition, Chicago, Ill.

ANOTHER GRAVER ANSWER TO A WATER STORAGE PROBLEM

This 400,000 gallon elevated water tank for Plymouth, Indiana, is another example of Graver's skilled craftsmanship in steels and alloys. Graver's nationwide organization and 100 years of experience in the design, fabrication and erection of all types of storage tanks can be of valuable assistance in solving your water storage problems, too! Write today for information. **GRAVER TANK & MFG. CO., INC.**

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Pittsburgh • Detroit • Chicago • Tulsa • Sand Springs, Okla.
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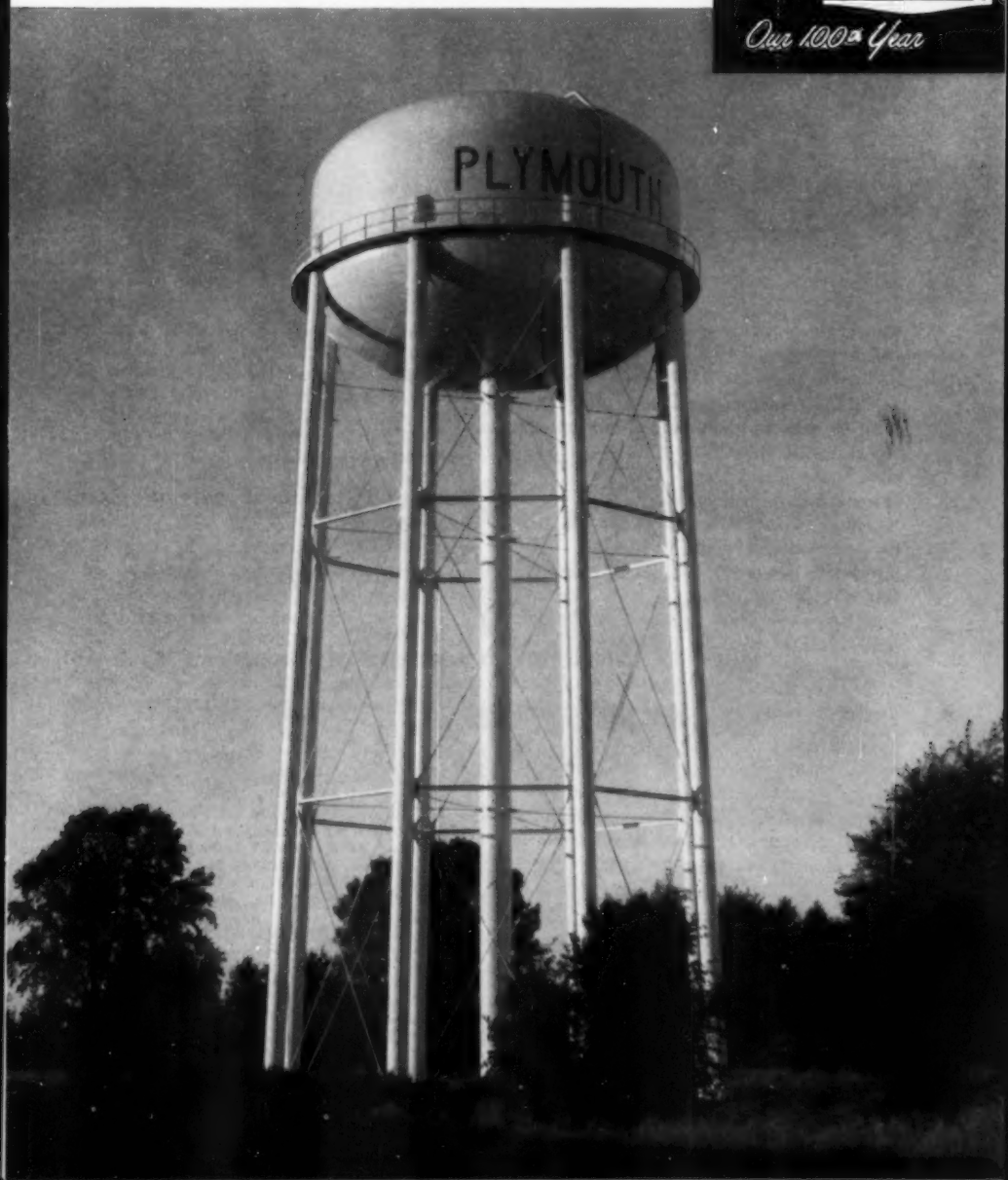
1857-1957 GRAVER Our 100th Year



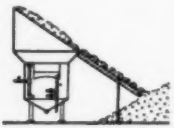
Getting best results from your soft-water installation?

To be sure your softeners are working at peak efficiency, regeneration must be complete. This article is number 9 in a series prepared by International Salt Company on the use of salt and brine in regeneration.

Combining storage and feeding makes salt handling easier

You can save both time and manpower in salt handling by installing a salt-storge unit that feeds directly into a salt dissolver. Here are four of the most practical designs for combining salt storage and feeding. One of them—or an adaptation of the basic design—may be effective in saving floor space and lowering salt-handling costs for you.

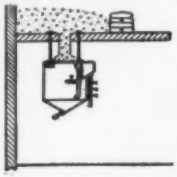
1. Filling dissolver from floor pile. If salt must be stored in bulk on the same floor as the dissolver (the dissolvers shown here are International's famous Sterling Model Lixators), an excellent feeding device is a portable belt conveyor. The best type for moving salt is made of aluminum with a rubber belt, and is between 16′ and 20′ long.



2. Overhead storage with vertical chute. This direct-feed unit is a practical, economical way of operating the Lixator. If storage capacity on floor above is large enough, no hopper is needed, which means a considerable saving. Feed is automatic because of angle of repose for salt.

3. Pyramid-type hopper design. This is another variation of overhead feed, coupled with large storage capacity. But if storage space on floor above is limited, this design is also practical. Salt can simply be dropped into the hopper through a large hatch with a removable cover

4. Lixator hung above floor, to save floor space. A very desirable design when floor space is at a premium. Design here also shows use of a few salt bags to act as a storage-bin wall—in place of a permanent bin structure.



One final note about the equipment discussed here. All Lixators operate on exactly the same principle. They vary only in size and capacity, and in methods of delivering salt to the dissolver unit. All Lixator designs are exclusive International Salt Company developments, properly protected by patents and patents pending.

Salt—and technical service—from International

Through skilled and experienced "Salt Specialists," we can help you get greater efficiency and economy from the salt or brine you use for regeneration. International produces both Sterling Evaporated and Sterling Rock Salt in all types and sizes. So we can recommend the type and size of salt most perfectly suited to your needs.

If you'd like to get this technical assistance—or any other information on salt or brine—simply contact your nearest International sales office.

SALES OFFICES: Atlanta, Ga.; Chicago, Ill.; New Orleans, La.; Baltimore, Md.; Boston, Mass.; Detroit, Mich.; St. Louis, Mo.; Newark, N.J.; Buffalo, N.Y.; New York, N.Y.; Cincinnati, O.; Cleveland, O.; Philadelphia, Pa.; Pittsburgh, Pa.; Memphis, Tenn.; and Richmond, Va.

INTERNATIONAL SALT CO., INC.

SCRANTON 2, PA.

Test after test, made by various independent research organizations, conclusively prove that DURAJOINT Waterstops are the only waterstops available on which you can stake the safety of your design and reputation. The results of these tests plus the many other advantages offered by DURAJOINT Waterstops are concisely stated in our new Waterstop Manual No. 457. Check and mail the coupon below for your free copy . . . it will make an excellent addition to your waterstop file.

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DEPT. 34

☐ Please send me, without obligation, a copy of Manual No. 457.

☐ Have Representative call.

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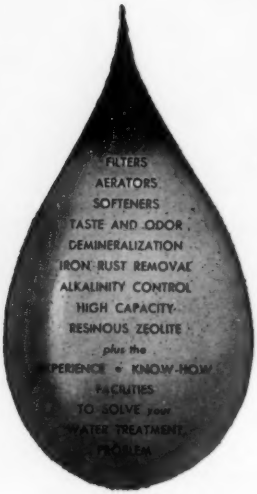
A GENERAL FILTER

WATER TREATMENT PLANT WILL FIT YOUR NEEDS LIKE A

Prescription!



That's right! General Filter actually *prescribes* a water treatment plant to fit the individual needs and requirements of each industry or municipality . . . designs, engineers and constructs it to assure an adequate supply of *pure* water . . . to provide dependable, economical, trouble-free operation over the years.

That's why more and more industries and municipalities are installing General Filter water treatment plants. They *know* they can depend on General Filter to solve their problem the *right* way. No job is too big or too small. General Filter's field-trained water specialists will *prescribe* a plant . . . its experienced engineers will *design* it and its skilled construction engineers will *build* it to fit your needs *exactly*.

Find out how General Filter solves Water Treatment problems for Industries and Municipalities . . . Find out how General Filter can solve yours

Write today for complete information . . . no obligation . . .

General Filter Company

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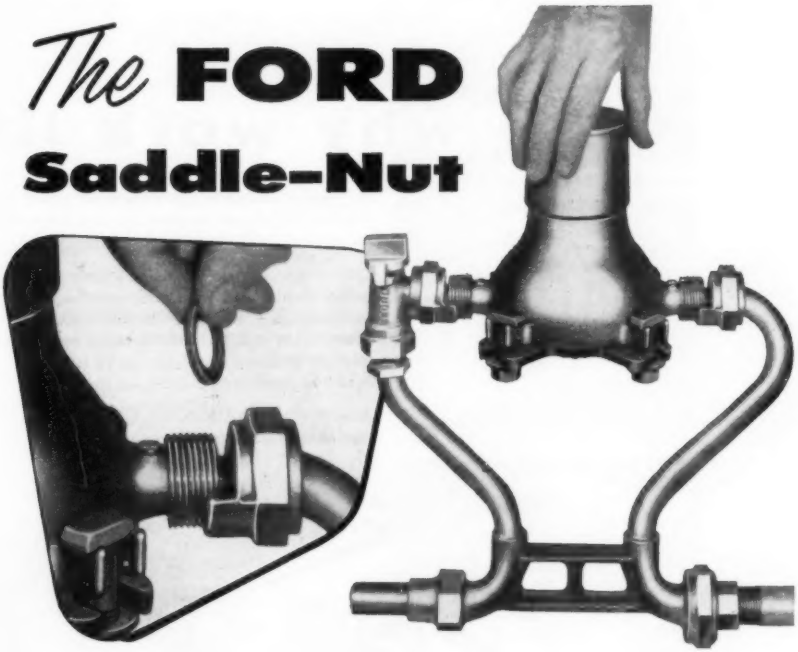
"yours for better water"

The FORD Saddle-Nut



HOLDS the meter for you!

Save time . . . . Save trouble . . . . Save gaskets, by putting the FORD SADDLE NUT at inlet, or both ends of every meter installation.

The patented Ford Saddle Nut has a supporting lip extending about half way around the meter nut, so that it supports the weight of the meter, lines up the threads of the nut with the meter spud, and provides a place to hold the gasket before the nut is screwed onto the meter.

The Ford Saddle Nut is available on all Coppersetters and Resetters at a small additional cost.

Send for Complete Information.

FORD

FOR BETTER WATER SERVICES

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

why work like a

No need to when you lay Tyton Joint® pipe. This quick and easy-to-assemble pipe goes in so smoothly it's a pleasure to work with.

Only one accessory needed—a simple rubber gasket that fits in the receiving pipe bell and is compressed by the entering spigot to permanently seal the joint. No bell holes. No weather worries, Tyton Joint can be laid in rain or wet trench.

A word of warning, however: make sure your trenching machine gets an early start or

U.S. cast iron PIPE FOR WATER, SEWERAGE AND

e a dog?

your laying crew—even an inexperienced one—will catch up fast.

Like all the facts on this new, time-and-money-saving pipe? Call or write today.

U. S. PIPE AND FOUNDRY COMPANY
General Office: Birmingham 2, Alabama

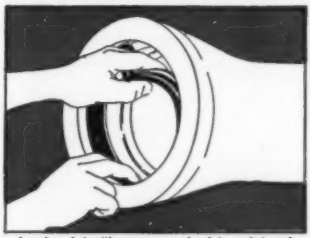
A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE

"WE NEED A COUPLE MORE DAWGS, GRAN'MAW...WE'RE LAYIN' THE TYTON FASTER'N THEY KIN DIG"

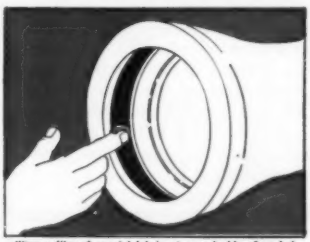
INDUSTRIAL SERVICE

TYTON JOINT

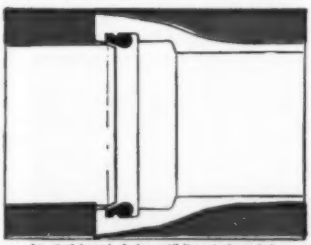
ONLY FOUR SIMPLE ACTIONS



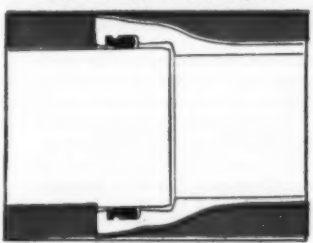
Insert gasket with groove over bead in gasket seat



Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



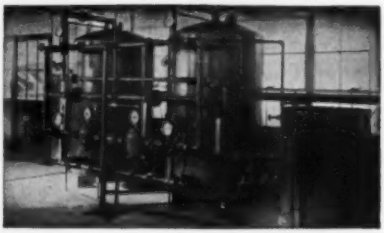
Force plain end to bottom of socket . . . the job's done!

Roberts Filter *means...*

MUNICIPAL WATER PURIFICATION

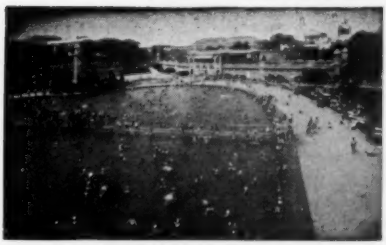
The combined capacity of Roberts-equipped filtration plants is well over 5 billion gallons (5,000,000,000) per day. Regardless of the size of the plant or the nature of the filtration problem, Roberts Filter can be depended upon for equipment that is reliable in years of service.

INDUSTRIAL WATER RECTIFICATION



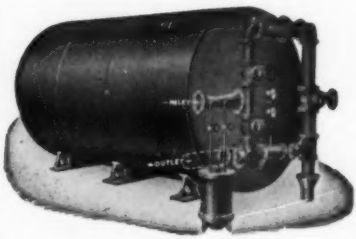
Water treatment has long been a specialty of Roberts Filter. Zeolite water softeners are guaranteed to meet all requirements for which recommended, and are available in a wide range of capacities. Roberts water conditioning equipment is widely used to control precisely the desired chemical content of water for industrial use.

SWIMMING POOL RECIRCULATING SYSTEMS



The combination of thoroughly clarified water and efficient recirculation are features for which Roberts pools are famous. Systems for both outdoor and indoor pools are designed and installed by men long experienced in the conditions peculiar to a successful swimming pool installation.

PRESSURE FILTERS



Closed pressure filters have wide usage where gravity filters are not justified. Roberts vertical filters are available in standard types from 12" to 96" diameter; horizontal pressure filters are all 8'0" in diameter and in varying lengths from 10'0" to 25'0".

When you think of good water—think of Roberts Filter

MECHANICAL EQUIPMENT BY ROBERTS FILTER MFG. CO.

Roberts Filter
Manufacturing Company • Darby, Penna.

TAPPING MACHINES

It Pays to Buy

HAYS®

- Modern Improved Design
- Designed for the Man in the Ditch
- One Third Lighter
- Easier to Handle
- Easier to Operate
- Speedier Operation
- Use with Any Standard Make of Stops
- See for Yourself What it Will Do for You

MODEL B ALUMINUM ALLOY TAPPING MACHINE

COPPER METER SETTERS

MAIN DRILLING MACHINE

CORPORATION STOP

ROUNDWAY CURB STOP

Join the A. W. W. A. HAYS is one of the eleven Charter Members of the Manufacturers Section of the American Water Works Association.

HAYS®

WATER WORKS PRODUCTS

HAYS MANUFACTURING CO.

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Here At Last...A superior flexible plastic pipe!

ORANGEBURG®
SP Plastic Pipe

Slit-Proof...Does Not Pin-Hole
Takes Higher Pressures
Has Greater Strength

ORANGEBURG SP is the only flexible plastic pipe, made from a superior new-type polyethylene resin, which took ten years of research to perfect. This resin's extremely high molecular weight gives exceptional strength and service life... *superior qualities found only in Orangeburg SP Plastic Pipe.*

PROVED SUPERIORITY— ORANGEBURG SP Pipe exceeds every test known for polyethylene pipe! Does not crack, break or corrode. Defies rough handling, hot sun and freezing temperatures. Smooth bore increases flow capacity, prevents build-up of pressure reducing deposits.

IDEALLY SUITED FOR water service lines, jet wells, irrigation lines, underground sprinkler systems, swimming pools, water and drainage lines during construction, chemical process lines —and many other installations.

SPECIFY ORANGEBURG SP —made in ½" to 2" sizes. Weighs only ⅛ as much as steel, installs fast and at low cost. Write Dept. JA-117 for more facts.

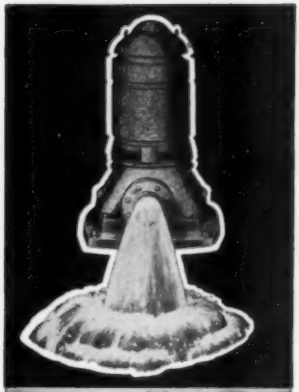
ADVANTAGES

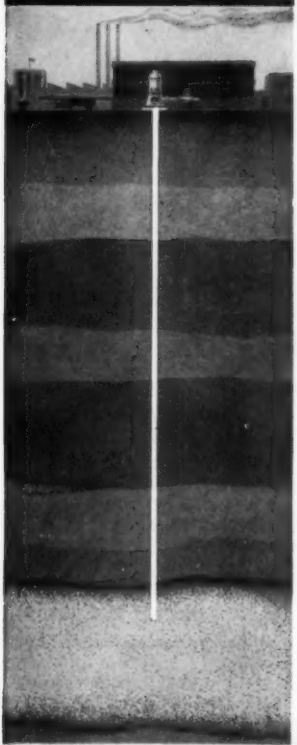
- Slit-proof (no "pin-holing")
- Greater strength
- Unaffected by detergents or soap solutions
- Higher heat resistance
- Exceptional resistance to kinking
- Resists acids, alkalies, salts
- Light, flexible, easily handled
- Lengths to 400', fewer fittings
- Low installed cost, lasting service

APPROVED FOR DRINKING WATER SERVICE BY NATIONAL SANITATION FOUNDATION

Backed by ORANGEBURG'S 64-year reputation for quality

ORANGEBURG MANUFACTURING CO., INC., Orangeburg, N.Y., Newark, Calif.





Layne knows more about water bearing formations!

This knowledge gained through 75 years of experience is a "plus" factor in any phase of Layne's service.

Knowing where the water is—and then tapping the subterranean source is but a part of the vast knowledge the Layne organization has accumulated in three quarters of a century.

Exploration, drilling, wells, pumping equipment, maintenance — in short any problem or phase of ground water development, think first of Layne.

Experience plus a world-wide reputation for economy, dependability and service are your best guarantee for more water at less cost.

Write for your copy of bulletin No. 100 for more detailed information.

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General Offices and Factory • Memphis 8, Tennessee

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

EXPERIENCED HELP NOT NEEDED

to clean your own WATER MAINS!

It's easy... it's economical... it's convenient... WHEN YOU DO IT YOURSELF!

Pipe cleaning with "Flexibles" requires no special skills because tools and methods are so basically simple. Many cities contract cleaning costs of 12¢ per foot have been reduced to around 3¢ by using "Flexible" tools and regular employees. Other advantages: you clean at your own convenience, during slack periods — and with less inconvenience to customers.

PRESSURE LINE SCRAPER METHOD
For long runs and light deposits.

Inserted in cut-out section of main, it travels by water pressure — cleaning as it goes. Scrapings are deposited on street level by scraper as it emerges from the riser.

CHAIN HEAD AUGER METHOD
For short runs and hard deposits.

Operated by Flexible Power Drive, centrifugal force drives hard-faced chain knockers against encrustations, chipping, cracking, smoothing.

For further facts or Catalog 55-B on "Do It Yourself," write for name of the nearest Flexible Distributor

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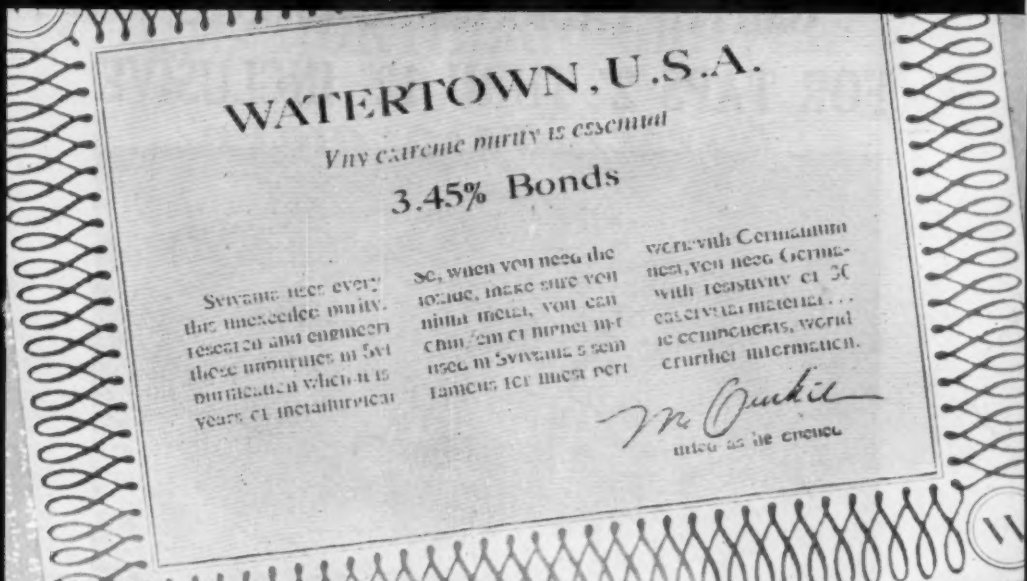
WITH CELITE DIATOMITE FILTRATION
YOU CAN GET CRYSTAL CLEAR WATER AND...



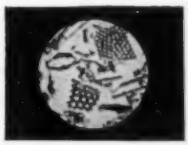
Cut capital filtration costs as much as 45%

An actual installation by Johns-Manville established that a Celite* filter station can be constructed for 55% of the cost of a comparable sand filter plant.†

Diatomite systems not only cut costs, but, under comparable conditions, they also improve water clarity. For with Celite, turbidity is usually lower since more suspended impurities, including all floc, amoebae and algae, are removed. In fact in some cases, turbidity is so low it can't be measured.

Diatomite systems save space, too. To deliver the same installed capacity requires a sand filter plant 4 times as big.

Mined by Johns-Manville at the world's largest and purest commercial diatomite deposit, Celite is carefully processed for purity and uniformity. It is available in a wide range of grades to deliver the best practical balance of clarity and flow rate with any suitable filter. For further information see your nearby Celite engineer or write for free technical reprints and illustrated brochure to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.



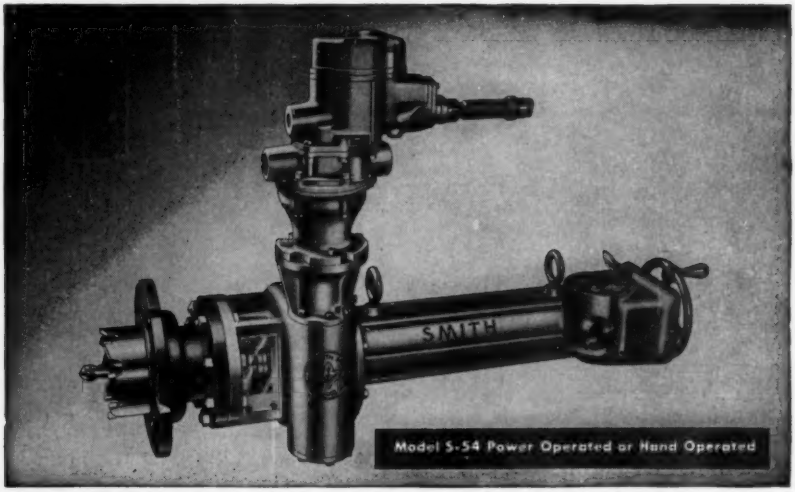
Celite filter aids are composed of microscopic, irregularly-shaped particles like these. 90% of a given quantity of Celite is composed of countless channels and voids that trap the finest impurities while permitting the free passage of clear liquid.

*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products. †See *Comparison Studies of Diatomite and Sand Filtration* by G. R. Bell, Journal American Water Works Association, September, 1956, or write for free reprint.

JOHNS MANVILLE PRODUCTS

Johns-Manville CELITE Filter Aids

SMITH TAPPING MACHINES FOR TAPS 2" THRU 12" INCLUSIVE



Model S-54 Power Operated or Hand Operated

The Smith S-54 Tapping Machine is the most modern, efficient and economical machine available. S-54 Machines are produced with either 25" or 37" travel. The Machine is used with Tapping Sleeves, Hat Flanges, Saddles and Tapping Valves to make 2" through 12" connections under pressure to Cast Iron, Cement-Asbestos, Steel and Reinforced Concrete Pressure pipe. Features: 1. Positive automatic feed insures correct drilling and tapping rate. 2. Travel is automatically terminated when tap is completed—cutter and shaft cannot overtravel. 3. Telescopic shaft reduces overall length. 4. Mechanism is housed in heat treated Aluminum Case filled with lubricant. 5. Stuffing Box and Packing Gland is accessible without disassembling machine. Line pressure cannot enter machine case. 6. Extra large diameter telescopic shaft adds strength and rigidity. Timken radial-thrust bearings maintain alignment, reduce friction and wear. 7. Worm gearing operates in lubricant, torque is reduced to the minimum. 8. Cutters have replaceable Flat and Semi-V alternate teeth of High Speed Steel or Tungsten Carbide. 9. Flexibility: Hand Operated Machines can be converted to Power Operation by interchanging worm gearing. Bulletin T54 sent on request.

53

THE A.P. SMITH MFG. CO.
EAST ORANGE, NEW JERSEY

USE NORTHERN GRAVEL
for
RAPID SAND FILTER

FILTER SAND SPECIFICATIONS are carefully laid out. The Effective Sizes and Uniformity Coefficients used by Consulting Engineers and also recommended by the American Water Works Association are the result of long years of research and experience.

The Northern Gravel Company is equipped to give you prompt shipment whether it be one bag or many carloads, exact to specification. Filter sand can be furnished with any effective size between .35 MM and 1.20 MM.

CHEMICAL QUALITY of the filter sand is also important. It must be hard, not smooth and free of soluble particles. This requires perfect washing, and grading facilities. We have every modern device for washing, drying, screening and testing.

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The new Northeast Station in the City of Detroit, recently completed, is one of the major projects included in the water department's expansion program. The Northern Gravel Company furnished 120 carloads of filtering materials for the 48 rapid sand filters incorporated in this plant.

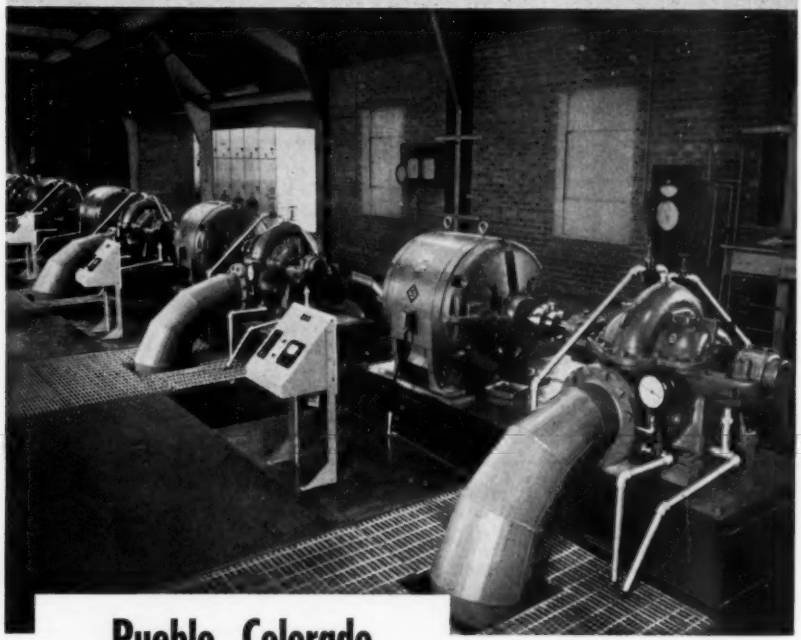
Northern Gravel has no equal in facilities and our reserves of both sand and gravel are inexhaustible. Northern Gravel Company has been in business over 40 years. We guarantee uniformity of products and our records enable us to duplicate your requirements on short notice. Our location is central and we have commodity rates in every direction.

NORTHERN GRAVEL COMPANY

Muscatine, Iowa

P.O. Box 307 **Phone: Amherst 3-2711**

Allis-Chalmers PUMPS solve a water works problem



Pueblo, Colorado again purchases Allis-Chalmers Equipment for increased water capacity

Public Water Works No. 2, Pueblo, Colorado . . . two 12 by 10 SHS pumps, 3500 gpm, 290-ft head, driven by 350-hp, 1770-rpm Allis-Chalmers motors — and three 12 by 10 SH pumps, 6000 gpm, 290-ft head, with 600-hp, 1770-rpm Allis-Chalmers motors.

This progressive industrial city of over 100,000 expects to double its population in less than 30 years. This growth pattern called for immediate increased capacity and plans for future expansion. Because Allis-Chalmers pumps have been giving long, dependable service with minimum maintenance, Pueblo specified Allis-Chalmers again.

Why you get MORE pump value when you specify Allis-Chalmers

You draw on Allis-Chalmers wide experience in supplying pumps for public works . . . for expert engineering and application help. You get pumps made of best-quality materials, of heavy duty construction, of high-efficiency design. Allis-Chalmers is the only company that offers you "one source" responsibility, with a complete unit — pump, motor and control — all built to work together — all built by Allis-Chalmers.

For MORE information, call your local A-C office, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

A-C ALLIS-CHALMERS

A-5295

ALLIS-CHALMERS

The mark of LOWER FIRE INSURANCE RATES

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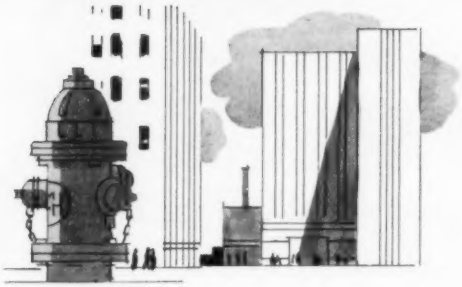

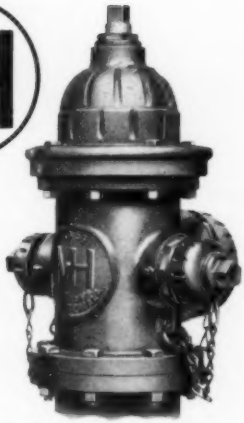

Standard model

Traffic model

Along the streets of hundreds of U. S. villages, towns and cities stand modern sentinels of fire protection: M & H fire hydrants. Where you see them, too, you can be reasonably sure they are the mark of lower fire insurance rates. Assuming an adequate water supply, an efficient distribution system and a fire department, M & H hydrants are the last of the four principal factors which mean good fire protection and lower insurance rates.

An M & H hydrant may long stand idle, yet functions perfectly when needed. Large inside diameter and unobstructed waterway gives high flow efficiency. Operating parts are bronze or bronze bushed. Furnished either UA & FM approved or A.W.W.A. specification, standard model, traffic model or flush type. For complete information, address

M&H VALVE AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF WALWORTH

Allis-Chalmers PUMPS solve a water works problem

Pueblo, Colorado again purchases Allis-Chalmers Equipment for increased water capacity

Public Water Works No. 2, Pueblo, Colorado . . . two 12 by 10 SHS pumps, 3500 gpm, 290-ft head, driven by 350-hp, 1770-rpm Allis-Chalmers motors — and three 12 by 10 SH pumps, 6000 gpm, 290-ft head, with 600-hp, 1770-rpm Allis-Chalmers motors.

This progressive industrial city of over 100,000 expects to double its population in less than 30 years. This growth pattern called for immediate increased capacity and plans for future expansion. Because Allis-Chalmers pumps have been giving long, dependable service with minimum maintenance, Pueblo specified Allis-Chalmers again.

Why you get MORE pump value when you specify Allis-Chalmers

You draw on Allis-Chalmers wide experience in supplying pumps for public works . . . for expert engineering and application help. You get pumps made of best-quality materials, of heavy duty construction, of high-efficiency design. Allis-Chalmers is the only company that offers you "one source" responsibility, with a complete unit — pump, motor and control — all built to work together — all built by Allis-Chalmers.

For MORE information, call your local A-C office, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

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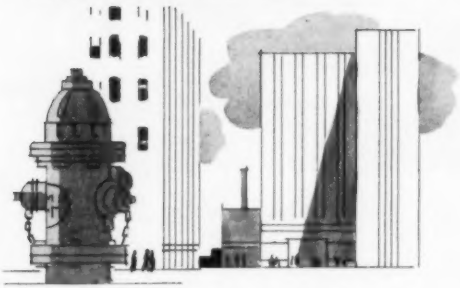

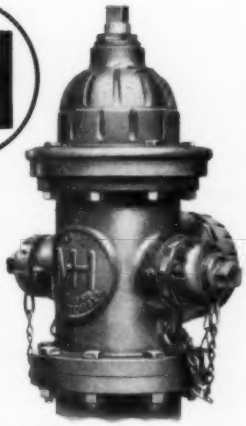

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Along the streets of hundreds of U. S. villages, towns and cities stand modern sentinels of fire protection: M & H fire hydrants. Where you see them, too, you can be reasonably sure they are the mark of lower fire insurance rates. Assuming an adequate water supply, an efficient distribution system and a fire department, M & H hydrants are the last of the four principal factors which mean good fire protection and lower insurance rates.

An M & H hydrant may long stand idle, yet functions perfectly when needed. Large inside diameter and unobstructed waterway gives high flow efficiency. Operating parts are bronze or bronze bushed. Furnished either UA & FM approved or A.W.W.A. specification, standard model, traffic model or flush type. For complete information, address

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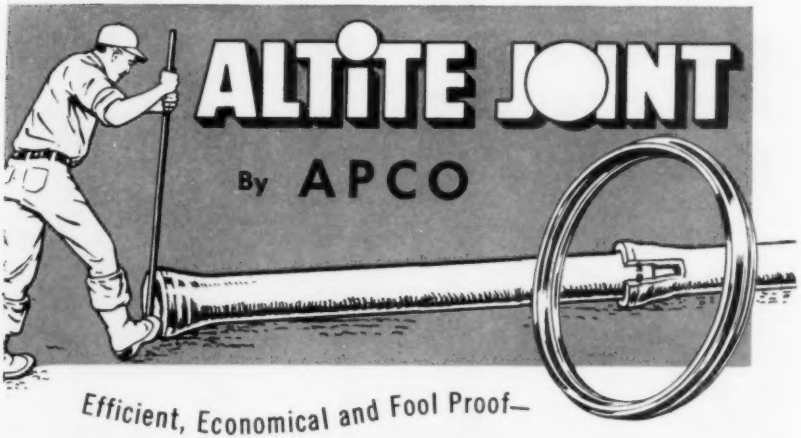

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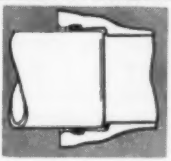
The **ALTITE JOINT** has been subjected to a series of rigid tests much more severe than are encountered under the most extreme installation and service conditions in the field. Even under extreme conditions, this joint is so simple to install—you could hardly go wrong if you tried.

Four Operations As Simple As Falling Off a Log—

Insert Rubber gasket in bell end of pipe—you can't put it in wrong—a child can do it.

Wipe on a small amount of special lubricant—this reduces friction.

Insert plain beveled end of pipe—there are no grooves, ridges or tips on gasket to interfere with smooth insertion.



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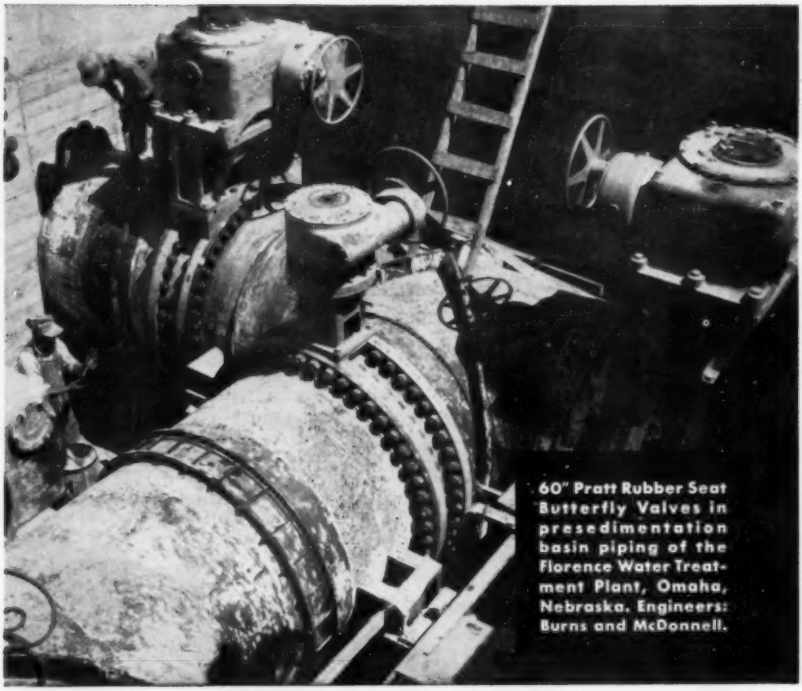

60" Pratt Rubber Seat Butterfly Valves in presedimentation basin piping of the Florence Water Treatment Plant, Omaha, Nebraska. Engineers: Burns and McDonnell.

OMAHA ... Butterfly Valves are key to compact piping

This ultra-compact arrangement of three 60 inch valves could only be made with Butterfly Valves. The illustration shows the narrow face-to-face dimensions (only 15") and the compactness of the valve-operator assemblies. What you can't see is equally important! The rugged internal construction—the rubber seat that is never under severe pressure from the valve disc, only partially displaced during closure ... features that mean years of easy operation without maintenance problems or costs.

Pratt originated the Rubber Seat Butterfly Valve and has installed more of them than any other manufacturer.

For valve design with a 50 year reputation for practical imagination, see Henry Pratt.

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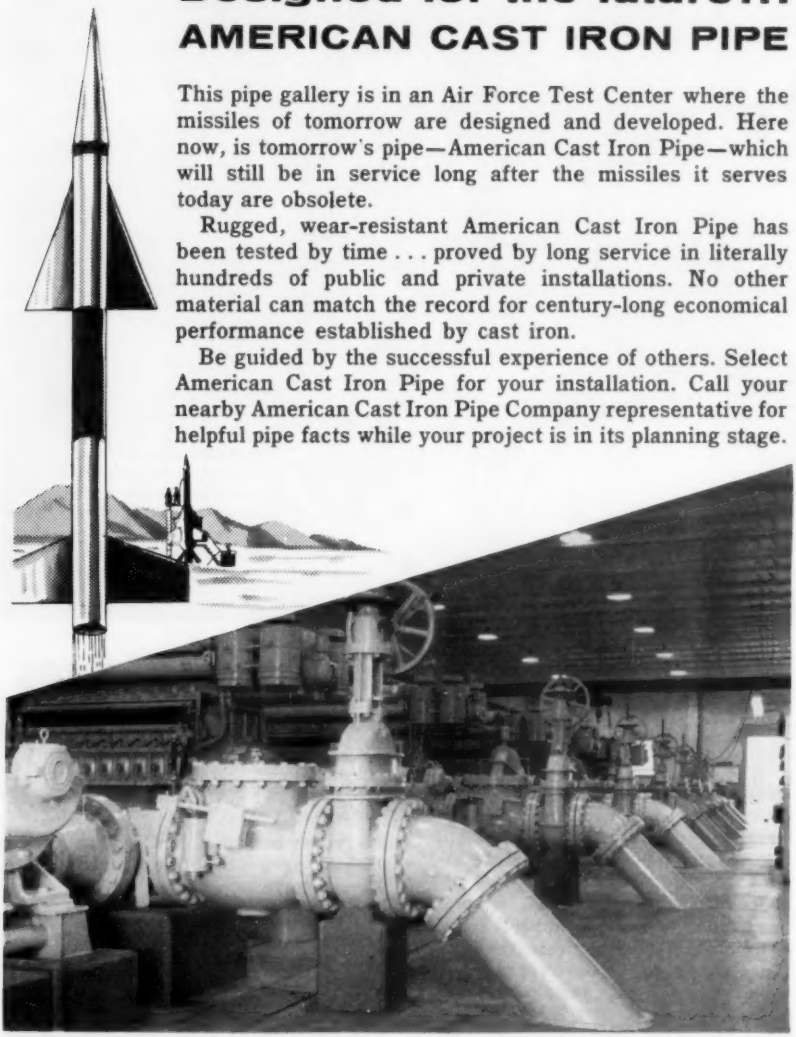

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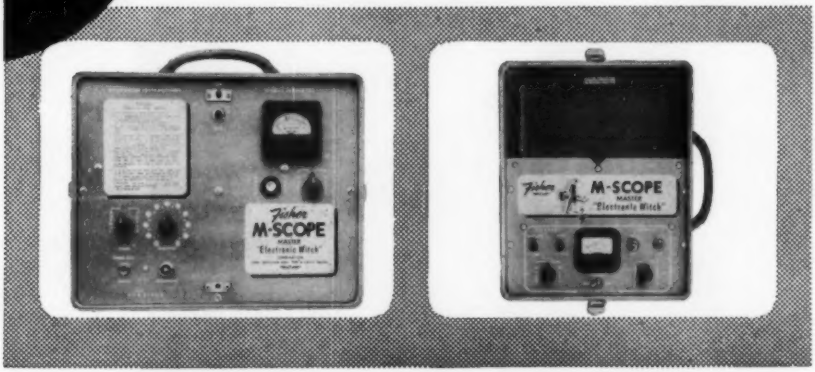

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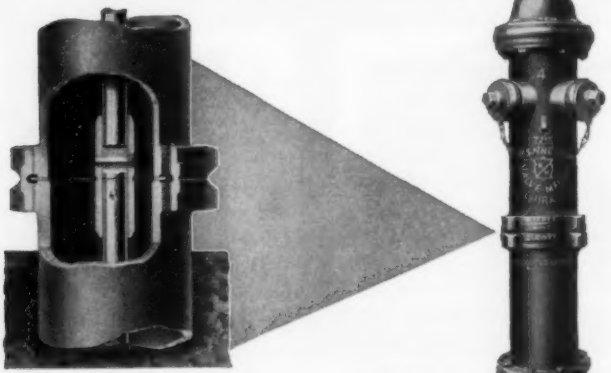
Here's How KENNEDY'S Safetop Hydrant Saves Maintenance and Repair Costs . . .



Construction of Safety Breakable Section of KENNEDY SAFETOP Fire Hydrant.

Fig. 1280
KENNEDY SAFETOP
FIRE HYDRANT

A broken KENNEDY SAFETOP . . . and all you need to repair it! When struck a smashing impact and broken, here's how the KENNEDY SAFETOP fire hydrant breaks. A clean break at the Safety Breakable Section means no damage to the major and expensive parts of the hydrant and no loss of water.

With this set of breakage repair parts, the repair job can be done by one man, with a few standard tools, without excavation. The entire repair job takes about fifteen minutes.

KENNEDY SAFETOP fire hydrants are designed and constructed with these outstanding features: Protection against flooding upon accidental breakage; maximum supply of water at nozzles available from supply main; minimum friction loss from inlet elbow to nozzle outlets; positive, complete drainage after operation to prevent freezing; leakproof valves and gaskets; easy fast inspection and renewal of operating parts.

Both **KENNEDY SAFETOP** and **KENNEDY STANDARD** fire hydrants are non-flooding compression type and are available in 4", 4½", 5" and 6" sizes. See how KENNEDY fire hydrants can save you time and money. Write today for complete details.

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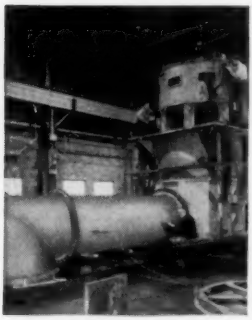
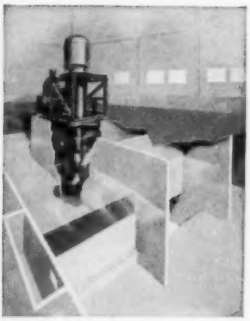
Here's why Wheeler-Economy Pumps you buy now



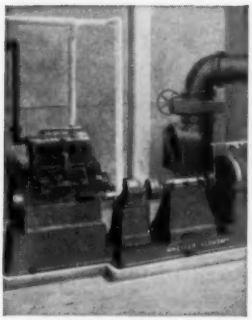
Wheeler's Pump Test Laboratory is one of the largest and best-equipped in the world! Every Wheeler-Economy Pump must pass exhaustive tests here before it's shipped to a customer.



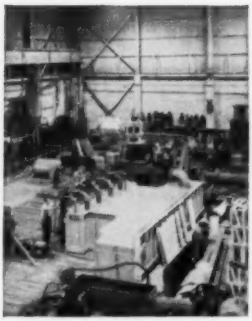
Precision venturi meters and weirs are used to accurately measure pump performance. Typical Circulator shown here pumps 46,000 gallons per minute, weighs 50 tons when filled.

An indoor ocean which holds thousands of gallons of water tests performance of pumps with capacities of from 10 to over 200,000 gallons per minute, and with total heads to 750 ft.

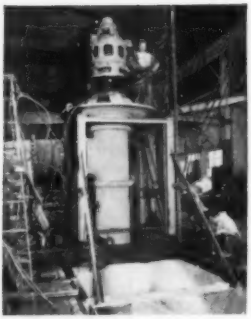
may still be operating efficiently in 1982!



This is one of many Wheeler-Economy Pumps still operating efficiently after 25 years' service—without replacement of major parts! Thorough testing is one of the many good reasons.



A unique part of our facilities is channel model testing—scale-model construction of complete water intake tunnel structures to study all flow characteristics prior to pump sale.



Another advantage Wheeler's Test Laboratory offers is the more rapid development of new pump designs. You can depend on Wheeler-Economy to be first with the newest pumps!

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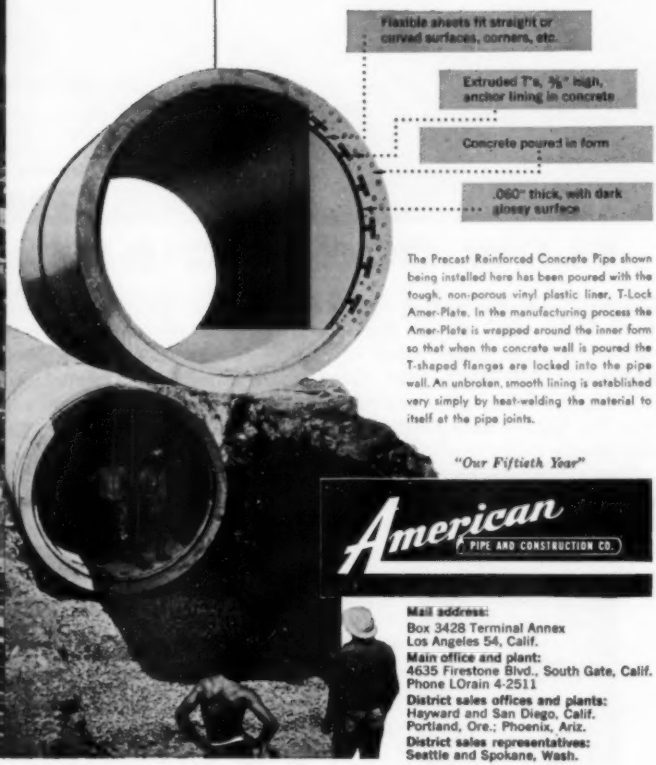
precast reinforced concrete pipe with...

locked-in protection

T-Lock Amer-Plate liner provides unequaled protection against corrosive acids, salts and alkalies and has proved to be impervious to high concentrations of hydrogen sulfide sewer gas.

The criterion by which a product is inevitably judged is its acceptance by the consumer. The Los Angeles Board of Public Works has awarded contracts for Precast Reinforced Concrete Pipe, protected by T-Lock Amer-Plate, for their large diameter main trunk sewer installations. Thus, this community can be assured of trouble free service, economical maintenance and maximum life in these lines.

The long recognized qualities of strength and durability in Precast Reinforced Concrete Pipe plus the added proven protection afforded by corrosion resistant T-Lock Amer-Plate are a sure guarantee of permanence and economy.


Flexible sheets fit straight or curved surfaces, corners, etc.
Extruded T's, 3/8" high, anchor lining in concrete
Concrete poured in form
.060" thick, with dark glossy surface

The Precast Reinforced Concrete Pipe shown being installed here has been poured with the tough, non-porous vinyl plastic liner, T-Lock Amer-Plate. In the manufacturing process the Amer-Plate is wrapped around the inner form so that when the concrete wall is poured the T-shaped flanges are locked into the pipe wall. An unbroken, smooth lining is established very simply by heat-welding the material to itself at the pipe joints.

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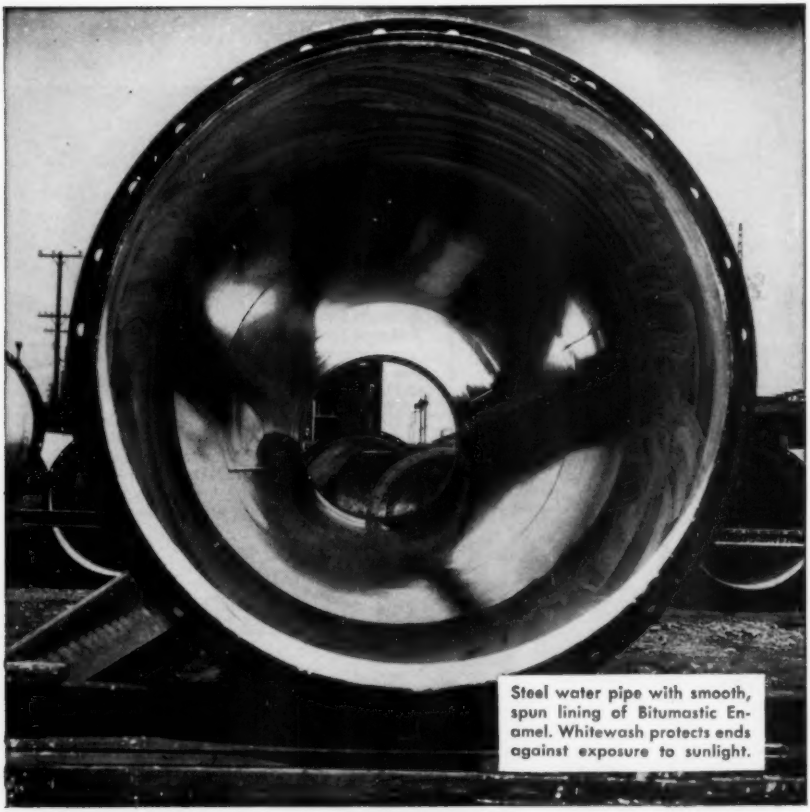

Steel water pipe with smooth, spun lining of Bitumastic Enamel. Whitewash protects ends against exposure to sunlight.

FLOW COEFFICIENT=155

The ebony-like finish on the inside surface of the steel water pipe shown above is a typical spun lining of Bitumastic 70-B AWWA Enamel. This type of lining has been tested and proved to have the highest flow coefficient available today.

That's one reason why steel pipe, lined with Bitumastic 70-B AWWA Enamel is such a good investment for water lines. Delivery stays high, too, year after year, since this enamel provides the best protection against tuberculation and incrustation known today.

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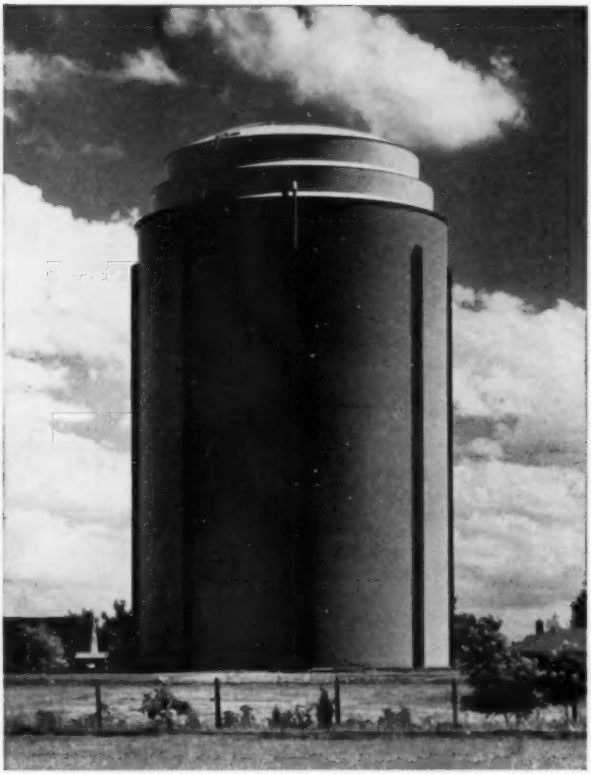
Standpipe Built With Special Design And Painting Scheme



Hinsdale, Illinois, Increases Water Storage With 2,000,000-Gallon Horton Standpipe

A water shortage was overcome in the constantly expanding community of Hinsdale, Illinois, as a result of an expansion program including the erection of a Horton Standpipe, with a capacity of 2,000,000-gallons. The standpipe has a diameter of 60 feet, a height of 99½ feet to the overflow pipe. Special consideration was given to the aesthetic appearance of the structure. The shell was painted pea green, the ribs a forest green for contrast and the set backs and roof a cloud grey to blend into the sky.

Write to our nearest office for an estimate or information.

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When you plan your new plant or the expansion of your present one, be sure to plan a place for W & T Dry Chemical Feeders as well as Chlorinators. W & T Feeders are used for every type of dry feeding problem found in water and sewage treatment plants.

W & T makes both volumetric (volume measurement) and gravimetric (weight measurement) feeders. There is a feeder for any size job, from small equipment to measure out ounces, to accurate giants capable of handling thousands of pounds per minute.

To find out more about W & T Dry Chemical Feeders, write for bulletin S-124. Or let us know the type of feeder problem you have, so we may send publications describing the W & T equipment best suited for your job.

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Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 49 • NOVEMBER 1957 • NO. 11

Telemetering and Remote Control by the Long Island Water Corporation

Samuel C. McLendon and Michael Zihal

A paper presented on May 13, 1957, at the Annual Conference, Atlantic City, N.J., by Samuel C. McLendon, Partner, H. G. Holzmacher & Assoc., Hicksville, L.I., and Michael Zihal, Head, Eng. Dept., Long Island Water Corp., Lynbrook, N.Y.

THE 44-sq mile service area supplied by the Long Island Water Corporation was among the fastest growing areas in the country during the years 1947–55. This area, immediately adjacent to New York City on the south shore of Long Island, has frequently been referred to as the bedroom of New York City. High peak load ratios are attributed to characteristically high residential demands, severe lawn sprinkling demands, and added peak load demands of a sizable influx of summer vacationers.

As shown in Fig. 1, from 1945 to 1955 the number of customers increased 78 per cent, the average daily pumpage increased 135 per cent, the maximum day increased 193 per cent, and the maximum hourly rate increased 170 per cent. The number of customers is computed from beginning and end of the year averages and does not include more than 1,000 seasonal customers nor more than 600 automatic lawn sprinkler installations.

Supply and Treatment

All of the supply is obtained from wells ranging in depth from 20 to 1,100 ft and in capacity from 50 to 1,600 gpm. The shallower depths and lower capacities are for older wells on a suction system which have or are being relegated to standby or reserve use. The well capacity is dispersed through portions of the territory at sixteen of the eighteen stations and can deliver a daily rate of about 55 mgd. About $\frac{2}{3}$ of the well capacity is equipped with high-head pumps, delivering directly to the system. Water treatment consists of chlorination of all supplies—sometimes for oxidation of hydrogen sulfide, but usually for precautionary reasons; corrosion control by the addition of

lime at all plants; iron removal at two of the plants; and metaphosphate application at a few plants to sequester smaller amounts of troublesome iron.

Distribution

Pumped ground level storage of 11.7 mil gal and 0.5 mil gal of elevated storage are available to supply varying peak hourly load demands to about 110 mgd. Sixty per cent of the ground storage is designed to operate as "double-pumped" storage, filled from the system during off-peak hours and pumped to the system during peak loads. Additional pumping costs are small, however, because this double-pumped storage is needed only a few days each summer and is only about 1 per cent of the total annual pumpage. With only a minute amount of elevated storage, which was erected in one section many years ago, the system is basically a closed one.

The largest mains—24 in.—extend to the edge of the system because before 1931 the company supplied a sizable area beyond present limits and within New York City. With the exception of the oldest supply at the main plant, and a new restricted-use installation to supply an island resort area, all of the well capacity is located in the northern third of the system. This is made necessary by the potential danger of salt water intrusion, which has occurred to varying degrees in some coastal areas of Long Island. Consequently, the general scheme of planning in the past several years was to install well capacity in the northern part of the area to supply that area's peak hour requirement and to supply the entire system's maximum daily requirement. The ability to obtain dispersed sources of supply makes possible transmission lines smaller than if sources were concentrated at fewer sites. This dispersion, however, presented problems of manpower in obtaining maximum operating efficiency.

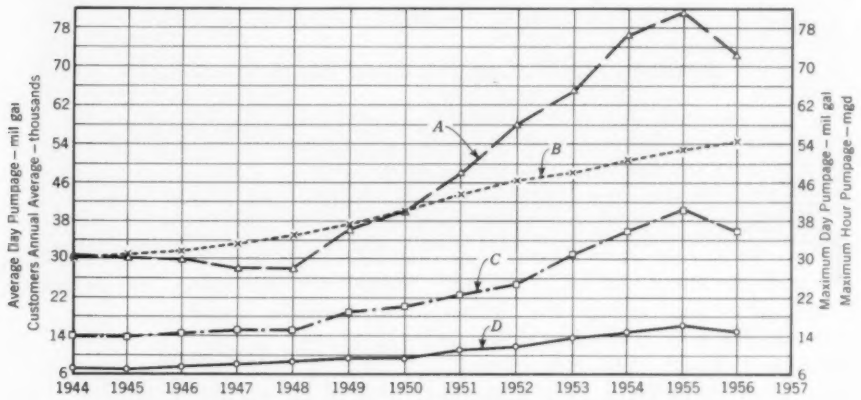


Fig. 1. Relation of Pumpage and Number of Customers

Curve A *is for maximum hour;* B *represents number of customers;* C, *maximum day pumpage; and* D, *average day.*

Before 1949, all supply was obtained from five plants, which included the main plant—a 24-hr plant that supplied about 70 per cent of the supply—and had no significant automatic con-

trols. Today, the main plant supplies about only 30 per cent of the supply, even after expansion and modernization (conversion from steam to diesel power). The other stations employed standard pressure-operated switches with thermal-type surge protection time-delay relays for automatic operation of the pumping units.

Automatic Controls

The first additional large plant was installed in 1949–50 and consisted of two wells, a ground level storage reservoir, and high-service pumps. The wells are automatically operated from pressure switches actuated by reservoir level. The high-service pumps, used to pump from the tank to the system, are equipped with a six-step, closed-system type, pressure-operated control unit with built-in adjustable time delay relays to minimize pressure surges when changing pump combinations. Reservoir level, rate of flow to system, and system pressure are telemetered to and recorded at the main plant. Remote operation to advance the control unit is transmitted from the main plant. The three telemetered functions utilize impulse-duration type instruments and the four signals are transmitted over one pair of standard leased telephone wires by using a-c and d-c current over each wire and using ground for return.

Similar transmission systems were installed in 1951 and 1952 at two new plants, both of which consisted of a ground level reservoir and booster pumps, but no wells. One of these systems was identical to that described except that the remote control function was used for remote valve positioning to vary rate of flow from the system to the reservoir and the flow rate *to* or *from* the system was the telemetered flow. Identification of flow direction was done automatically at the local station. The other system installed required an extra pair of telephone wires because, in addition to the three recorded telemetered functions and remote valve operation, remote operation of three diesel engines was provided. Of interest too, are two features of local control of the diesels. In addition to the usual safety cutout devices, each engine throttle was equipped with a low voltage reversible motor which, by means of time-delay relays, allowed each engine an idling warm-up period and an idling period before stopping. The engine speed, and consequently line or system pressure, may also be regulated by pressure switches, although because of subsequent plant additions, it is doubtful if this control will be needed in the future.

Because of continued rapid growth, backlog of supply deficiencies, and increased per capita use, new stations continued to be installed as rapidly as the engineering forces of the company could properly plan, design, and supervise them. By 1955, sixteen plants were in service, additions and improvements were made to older plants, and the installed supply, storage, and pumping capacity had been more than doubled from 1951, more than tripled from 1947. Two additional stations were under construction and a third under design. Most of the new well type stations were equipped with improved models of pressure switch automatic controls. Most were multiple installations provided with electrical interlocks to permit only the next pump in the prearranged sequence to start. In the interim, many of the well units were equipped with automatic blowoff valves. These automatic blowoffs are installed upstream of the discharge check valves and each well is automatically pumped to waste for a predetermined time when started and before

being stopped. This allows all air from the pump column and discolored water, if any, to go to waste and also minimizes system pressure surges when units start or stop.

Early Telemetering

In 1955, two of the older plants and one new plant were equipped with telemetering and remote control equipment. These were the first installations in this system which utilized audio tone transmission signals. This system was selected because: [1] existing telemetric equipment remained unaffected; [2] the need was becoming more acute for system-wide telemetering and remote control; [3] long distances would result in high costs for multiple leased lines; and [4] these installations would provide experience in planning for the future.

The older plants were equipped with telemetering equipment—for transmitting system pressure from those plants and recording it at the main plant—and with remote override of local automatic controls. The new plant was a ground storage, booster pump type station consisting of two 0.75-mil gal prestressed concrete tanks and three booster pumps with a total capacity of 7.4 mgd.

Tank level, rate and direction of flow, and system pressure are telemetered to the main plant by standard impulse-duration telemetering equipment in conjunction with the tone-transmission equipment. Remote control from the main plant includes override of the pump control unit (a multipump pressure switch) to increase or decrease remotely the number of pumping units operating. Remote control of back pressure and rate of filling of the storage reservoirs is accomplished by remotely operating a reversible motor—forward or reverse—to change the calibration of setting of a hydraulic controller, which in turn positions a hydraulically operated butterfly valve in the backflow or fill-storage bypass connection between pump suction and discharge piping. Local controls prevent backflow when pumps are operating.

Telemetering Considerations

Before making a decision, in 1956, to proceed with the installation of system-wide telemetering and remote control, time clocks and other local automatic devices were considered, but with extreme and unpredictable variable demands none offered a system-wide scheme of operation which, with remote control, could be manipulated by the operator at the main plant. It was conservatively estimated that on the maximum day at least one well plant, at a cost of at least $100,000, could be offset by the installation of remote control equipment for the remaining eleven local automatically controlled plants. This equipment, installed, was estimated to cost not more than $25,000. In addition, planned selection of units could reduce electrical demand and energy costs and in some instances provide a slightly better quality of water. The basic remote control scheme planned was to maintain local automatic control devices but relegate them to a secondary role in the event of failure of remote control signal or of operating personnel. Hence, the remote control signals were required to be of short duration rather than continuous and to fail in a "safe" or "off" position in event of power failure. In order to provide the central operator with information on pressures from all parts of the system to enable him to follow procedural instructions, it was decided to have pressures from each plant continuously transmitted and re-

corded. Continuous transmission was desirable to provide better indication of the execution of the pump start or stop signals, because pressure variations were greatest at the signaled station. Transmission of rates of flow from all wells would have added considerably to the cost, and was not justified at the time. Recording of the pressure was desirable because it provided the operator and supervisory personnel with trends throughout the system. A system which could be expanded or changed easily was highly desirable because future plant additions and changes were indicated.

Plans

Studies were made of the eleven locally controlled stations. Their location was considered with respect to each other and to other stations and with regard to multiple transmission (multiplexing) equipment costs as opposed to leased telephone line costs. It was decided to: [1] arrange the eleven stations and two other stations, already equipped, on three transmission circuits even though two would be adequate for present requirements; [2] utilize over each circuit continuous and simultaneous audio tone type transmissions; [3] utilize time impulse-duration type instruments for telemetered pressure measurements and recordings; and [4] install a panel of controls at the main plant and receiving and controlling relays at the outlying stations.

Just before ordering this equipment attention was directed to the availability of a d-c pulse system which seemed to offer economy if usable for the required remote control functions. After observing demonstrations of this equipment, it was decided to try it, particularly since, if it were found incompatible with the audio tone system, it could be used on another project planned at the main plant where small wells were dispersed over 180 acres. The economic advantage of this change was substantial and will become greater as additional control functions or signals are required.

Audio Tone System

The two types of equipment were ordered and application was made to the telephone company for three circuits of voice quality leased telephone lines, each circuit to be capable of transmitting signals of both systems simultaneously. The audio tone system employs a-c voltage signals in the audio or hearing range and was used for continuous telemetering of plant delivery pressures. The most common range of frequencies transmitted by this type system is 300–2,700 cycles per second. Companion equipment at the transmitting and receiving ends is tuned at a particular frequency—usually 100 cycles per second apart from other equipment used for another function. Frequency multiplexing is the general term applied to the transmission of many audio frequencies by a single medium, whether it be telephone line, microwave, or other. The audio tone transmitter consists of an oscillator, which is fixed, tuned, and sealed to generate a particular frequency. This tone of frequency is constantly generated and amplified as long as power is on the equipment. It is applied or keyed to the telephone lines by the conventional impulse-duration type telemetering transmitter, with the length of time the tone is applied relative to the magnitude of the measured function, such as pressure in this example. The audio tone receiver uses a filter designed to pass only a certain frequency band—that which would correspond to the

companion transmitter frequency. This signal is then amplified, rectified, and passed along to the conventional impulse-duration type telemetering receiver where duration of the tone is reconverted to a measured function and (in this instance) recorded on a pressure chart. Where tones are used for control functions such as starting or stopping pumps, operating valves, and others, pushbuttons are used to key the tone on the transmitting end and relays are energized via the tone receiver on the receiving end.

The number of audio tone channels is usually limited to about 25 per circuit but varies with distance and size of leased lines. The tone equipment may be installed on open racks as was done at the main plant; in wall-mounted enclosures, as was done at most outlying stations; or in free-standing panels incorporating conventional telemetering transmitters and receivers, as was done at one of the plants. The audio tone equipment * features plug-in type tone transmitters and receivers which, together with a plug-in type tester, aid considerably in maintenance of the equipment. Tone channels may be added on each circuit merely by adding equipment.

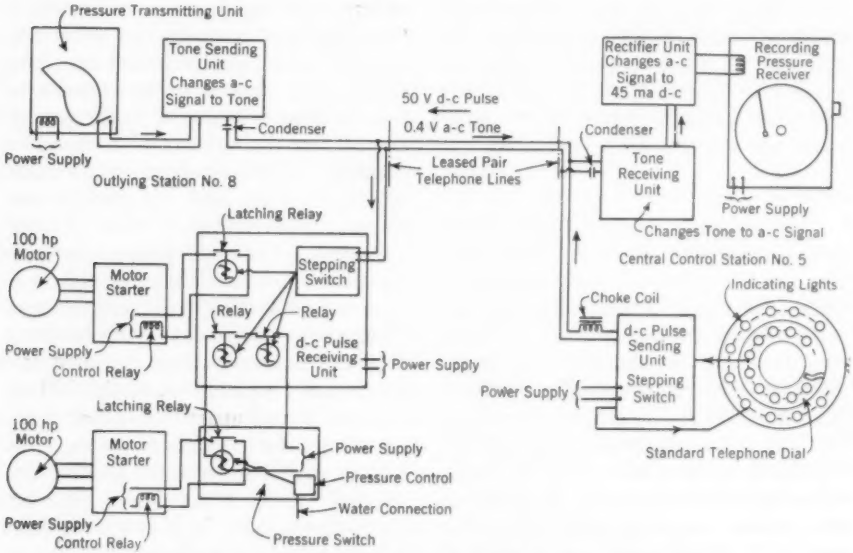


Fig. 2. Typical Telemetering and Remote Control Arrangement

Diagram is schematic of functions for one outlying plant of the Long Island Water Corporation.

Remote Control—D-C Pulse System

The remote control system for the eleven plants consists of one transmitting unit at the main plant and eleven receiving units, one in each of the eleven plants. The transmitter, which

* Supplied by the Hammarlund Mfg. Co., New York, N.Y.

generates 30- to 75-v d-c pulses, contains three separate channels or circuits, each equipped with two ten-position telephone dials. One dial transmits positive d-c pulses, the other negative. These coded pulses, originated by dialing the pump operation desired, are transmitted at the rate of ten pulses per second and are received at the outlying plants by polarized relays which, in turn, operate telephone type stepping switches or pulse-counting units. The received signal operates, through relays, the appropriate start or stop circuit of the outlying pressure switch. Since the desired remote control was to momentarily override the local pressure switch operation, two functions were required for each pump. The cost for extra functions was small compared to the trouble visualized if telephone line continuity were interrupted and all plants on that circuit thereby stopped. Of the ten positions on each dial the first two digits are not equipped for operation in order to prevent false signals from static-electric flashes (lightning). Each operating dial position is equipped with a pilot light which serves as a memory circuit for the main plant operator, telling him which pump operation signals have been dialed. He must watch his pressure recorders to ascertain the execution of the operation. This d-c pulse equipment,* though primarily designed for operation with its own conductors, may be superimposed on other systems if proper isolating equipment is provided.

A schematic wiring diagram of the functions involved to and from one outlying plant is shown in Fig. 2.

* Supplied by Taller & Cooper, Brooklyn, N.Y.

Systemwide Installation

The tone and telemetering equipment was installed and began operation in the fall of 1956. The remote control equipment was installed about the same time but did not go into permanent operation until February 1957. The d-c pulse signals interfered with the tone receivers because of the low impedance of the tone equipment. Since the installation of choke coils between the pulse transmitters and each telephone circuit, all equipment has operated satisfactorily.

No equipment is expected to be entirely trouble free, but it is too early to evaluate the maintenance required on this new equipment. A log is kept for all repairs and adjustments required on telemetering and remote control equipment for future evaluation and it is believed that maintenance of all this equipment will not be as great as that which would have been required for the additional plant which it, in effect, replaces.

Summary

Selection of automatic, telemetering, and remote control equipment must be individually planned for each water system or portion of a system in accordance with its needs. Many operations can be performed more reliably with automatic devices than with manual attendance—although for other operations the reverse is true. At the Long Island Water Corporation, the combined use of local automatic control, information telemetered from outlying unattended plants to a central point, and centralized supervisory or remote control override of local automatic control has already resulted and undoubtedly will continue to result in further improved service at reduced costs to its customers.

Automation and Remote Control of Chemical Feeders

Paul A. Coffman Jr.

A paper presented on May 14, 1957, at the Annual Conference, Atlantic City, N.J., by Paul A. Coffman, Vice-Pres., and Chief Engr. in charge of sales, Omega Machine Company, Division of B-I-F Industries, Inc., Providence, R.I.

OVER the past two or three decades, remote-control and automatic chemical proportioning systems have become an important consideration in the design and construction of water treatment plants. Many systems have been attempted, but only a few have survived the test of time.

Because it is not possible to list all of the known methods of automatic control in the space permitted an attempt is here made to define and describe the various automatic proportioning and remote-control systems currently used in water works.

Because any form of automatic or remote control requires additional equipment and expense, good engineering demands that it contribute materially to the performance of the particular plant or process; otherwise the additional expenditure for equipment cannot be justified.

Automatic proportioning or remote-control systems are desirable if they:

1. Provide better control of the process
2. Free manpower for other duties
3. Prevent waste or, in other words, contribute to more efficient use of chemicals
4. Contribute to safety (personal or public)
5. Increase production
6. Make service more reliable.

Definitions

The terms automatic proportioning, automatic control, or remote control are sometimes used rather loosely in the water works industry. For this reason, it is necessary to give careful consideration to the type of system used or the results obtained will be somewhat less than satisfactory.

The dictionary defines automatic control as ". . . that which has an inherent power of action to keep within limits." Each control system described conforms to this definition in varying degrees. No single system is satisfactory for all plants and, although names of systems vary with manufacturers, basic principles do not. No system can be recommended without consideration of plant requirements.

Remote Control

The simplest form of automation of chemical feeders is, perhaps, remote control or, probably better named, remote rate setting.

The systems shown in Fig. 1, 2, and 3 are used when it is necessary to set the chemical dosage rate for a group of feeders from a single control station.

There is no direct pacing or control loop from any instrument. Systems are used principally to localize control of equipment and they usually save manpower and contribute to more ef-

ficient operation because dosage adjustments are easily made from a central location. They are particularly valuable in a large plant where equipment is installed over a wide area.

Figure 1 shows an electric, remote rate-setting system which consists of a chemical feeder, a remote self-synchronizing motor, a transmitter, and a self-synchronizing receiver connected to the rate-setting handwheel of a variable-speed transmission.

It is the most accurate form of remote rate setting, because it is geared in such a manner that 100 turns of the handwheel on the control panel are needed to adjust the variable-speed transmission from zero to maximum rate. Indications are very precise and can be made to read directly in pounds or gallons per hour.

The addition of remote recorders is sometimes desirable with this system, but is not essential because of its range and inherent accuracy.

The system shown in Fig. 2 uses a chemical feeder (dry or liquid type), a pneumatically positioned variable-speed transmission device, and a pneumatic rate-setting panel. The range and accuracy of this pneumatic remote rate-setting system is limited to the repeatability and readability of pneumatic elements. The rate-setter panel is a high-grade pressure regulator and pressure gage.

If gravimetric feeders are used and close feeding accuracy ($\pm$ 1 per cent) is required, it is desirable to provide remote recorders for the feeder. Recorders are particularly worth while if the feeding range is more than 5:1.

A remote-control system using a variable-speed motor (Fig. 3) is sometimes used because it is easy to substitute a variable-speed motor for a standard one.

This system is subject to accuracy and range limitations because most variable-speed motors do not have good speed regulation at a range of more than 5:1, and show a repeatability error of 3–5 per cent.

Addition of a feedback generator improves the performance considerably but will not eliminate errors due to coarsely calibrated rate-setting potentiometers. There are a limited number of these in use in the water works industry.

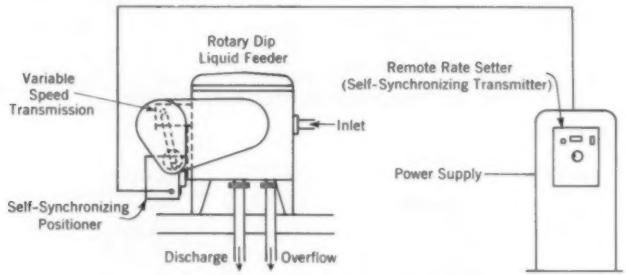


Fig. 1. Electric Remote Rate Setting System

Automatic Control

The most important form of automation to be considered is automatic control of chemical feeders. This general category embraces a number of pacing

and control systems. It should be noted that the term automatic control does not always mean a system with a complete control loop; a completely automatic control system must include:

1. A metering or measuring unit (venturi meter, pH meter, or weigher)
2. A controller (mechanical, electrical, or pneumatic)
3. A variable valve or feeder.

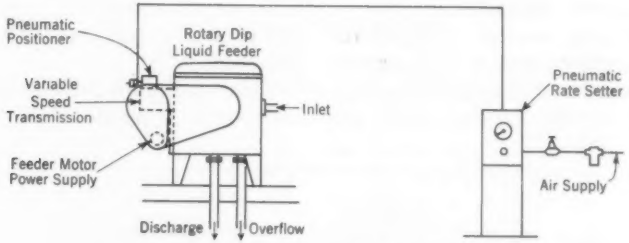


Fig. 2. Pneumatic Remote Rate Setting

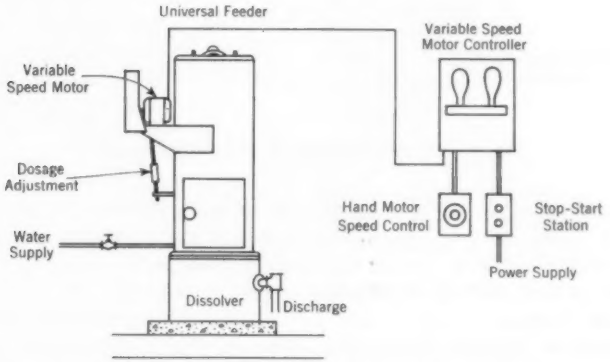


Fig. 3. Remote Control System With Variable Speed Motor

A completely automatic control system must include a report-back device connected to the controller.

In Fig. 4 a completely automatic control system is shown. Such systems which give proportional control by using a pH electrode and pneumatic controller are used for automatic control of pH and are subject to the physical layout of a plant in that equipment must be arranged for minimum lag time.

Many plants cannot use this system because of distance between various components and the duration and magnitude of process upset.

The principal elements of the system are:

1. A pH electrode
2. An amplifier
3. A pneumatic controller
4. A variable-rate chemical feeder.

In Fig. 4 the pH of the water flowing through the treatment tank is measured by the electrode, the signal is amplified in the amplifier, and the controller com-

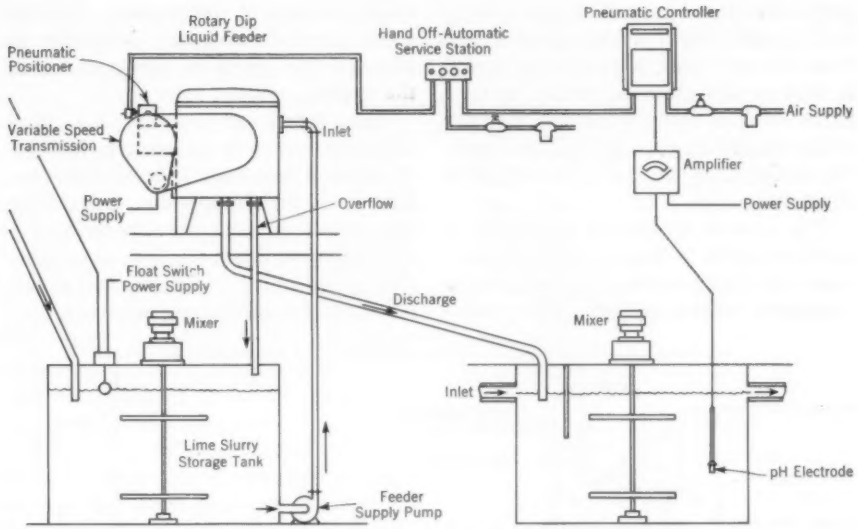


Fig. 4. Proportional Control Using pH Electrode and Pneumatic Controller

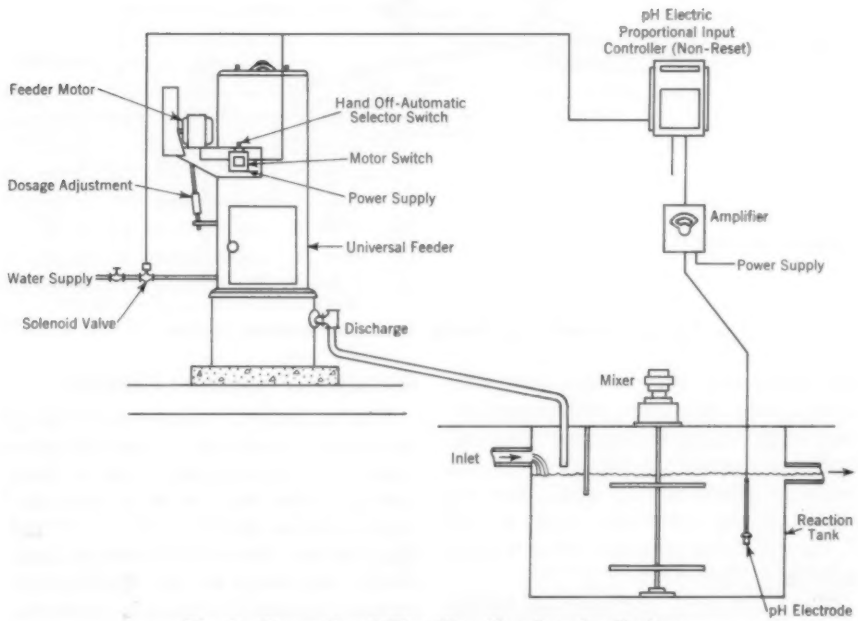


Fig. 5. Proportional Time-Duration Impulse System

pares the electric signal to the setting in the controller. If the signal varies from the set value, a pneumatic signal is sent to the chemical feeder to feed more or less lime to correct the pH of the water being treated. The chemical feeder may be either a liquid or dry type.

The system illustrated in Fig. 5 is similar to that in Fig. 4 in that it contains all the elements of a completely automatic control system. The principal difference lies in the controller which is equipped for proportional action only. This means that the controller will maintain the set pH value within a specified tolerance. For instance, if the controller is set at pH 7, the pH value of water being treated may vary from 6.8 to 7.2.

The band width is determined by the equipment arrangement and by the characteristics of the process. Instrument manufacturers can determine in advance the limits of performance of the system.

The signal to control the dry-chemical feeder is an electric impulse of variable duration. The feeder operates for a variable portion of a 15-sec period as required by the controller.

Equipment is simple, less expensive, and gives smooth performance if the installation requirements can be met.

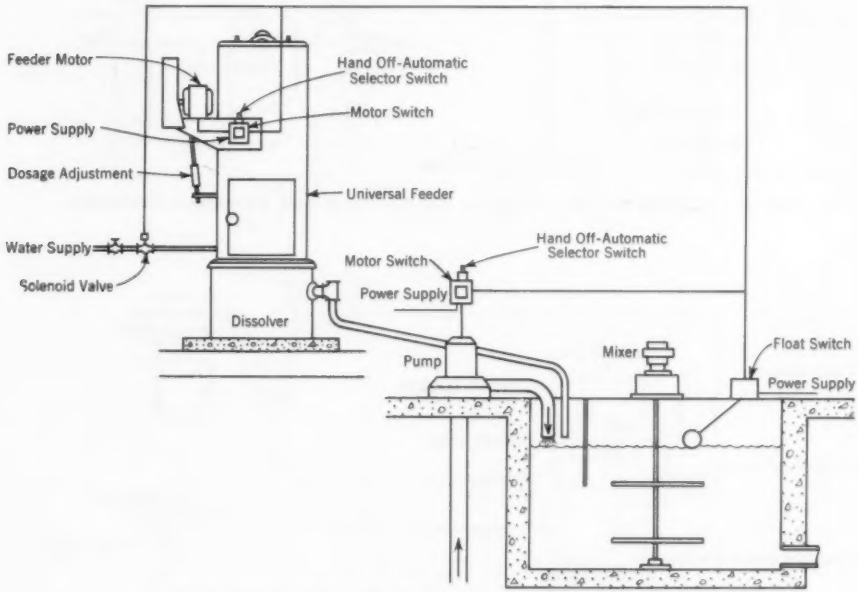


Fig. 6. Proportional Pacing With Intermittent Control

Automatic Proportional Pacing

The majority of water plants using any form of automatic control use automatic proportional pacing. All of these systems differ from the true automatic control system illustrated in Fig. 3 and 4 in that they do not have a report-back of the end result of the chemical reaction. Instead, a signal is generated by a primary metering device (me-

chanical, electrical, or pneumatic) and the chemical feeders are arranged to follow or *pace* the primary device.

The majority of these systems use some form of an intermittent electric time signal to start and stop the chemical feeders so that the running time of the feeders is proportional to the rate of flow through the primary device.

Other systems are arranged to change the speed or feed rate of a continuously operating chemical feeder. The latter system is more complex, more expensive, and requires more detailed engineering to insure a satisfactory proportioning system.

One of the earliest attempts to pace feeders automatically consisted in connecting the electric motor circuits in the chemical feeders and water pumps in parallel, to be actuated by a float switch in a tank (Fig. 6). This proportional pacing with intermittent control is a very simple system and there are many in use today.

The control equipment consists of a float switch and suitable motor-starting equipment. These systems are accepted as routine today, and it is hard to believe that they were quite an innovation in the not-too-distant past.

There are many forms of this type of pacing in which pressure, float, or temperature switches are used.

Step Control

A more complex variation of this type of control is the step or multirate control illustrated in Fig. 7. In this case, one, two, or three pumps are automatically started in a selected sequence in response to signals generated by float, flow, or pressure switches. A relay system is provided to actuate valves which cause the chlorine feeder to operate automatically and in proportion to the flow based on the number and selection of pumps. Similar systems have been built to pace liquid and dry feeders.

Time-Duration Impulse

The earliest and most widely used proportional-pacing system called proportional time-duration impulse is illustrated in Fig. 8.

This system * consists of the following principal pieces of equipment:

1. A venturi meter or similar differential producer
2. A transmitter

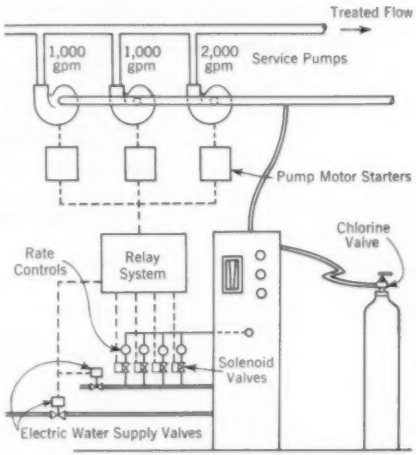


Fig. 7. Step Control of Chlorine Feeder

3. A chemical feeder with drive suitable for frequent starting and stopping
4. A relay and electric motor control equipment.

Water flowing through a venturi tube or a similar differential producer actuates a transmitter to energize the chemical feeder motor or drive circuit, for a variable part of each 15-sec pe-

* The system illustrated is the Chronoflo system, a product of Builders-Providence, Inc., division of B-I-F Industries Inc., Providence, R.I.

riod. A change in the flow rate through the differential producer results in a proportional change in the duration of the electric signal sent to the chemical feeder; thus, the running time of the feeder is proportional to the flow of water through the system. A secondary adjustment must be provided on the chemical feeder for chemical dosage adjustment.

If the feeder drive has objectionable coasting characteristics, and the system operates over a wide feeding range, a small time-delay relay is inserted in the circuit to nullify the coasting effect. Intermittent operation of the feeder does not affect the treatment process because the signals are so close together—every 15 sec—that the capacity of the dissolving chambers and treatment tanks evens the flow of chemical.

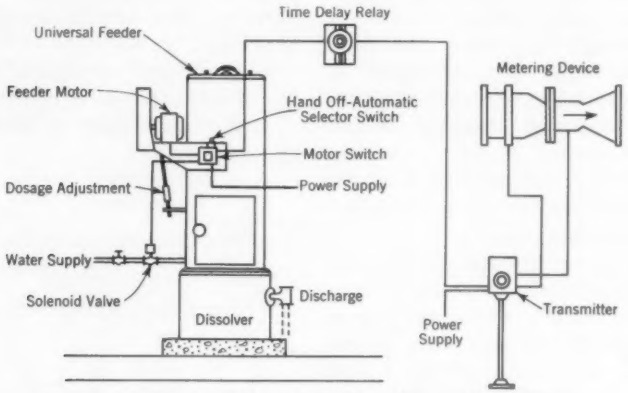


Fig. 8. Proportional Pacing Using Proportional Time Duration Impulses

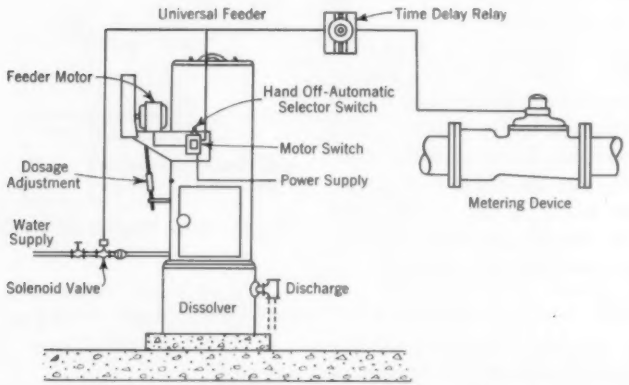


Fig. 9. Momentary-Contact System of Proportional Pacing

Momentary Contact

Another type of pacing system in current use is known as the momentary-

contact type. It is also called a time-delay control system. This system is used primarily with integrating type meters.

Figure 9 shows a universal feeder arranged for automatic proportional pacing from a propeller type meter with an electric contactor in its head.

The contactor is geared to make a momentary contact for a specified number of gallons passing through the meter. The momentary contact energizes the control circuit for the period for which it is set. In most cases this period is 15 sec. The belt shifter and solenoid valve, energized by the control circuit, cause the feeder and water supply to operate for 15 sec and then stop.

Thus, the feeder and water supply operate for 15 sec each time the meter contactor makes a momentary contact. At 100 per cent meter flow, the feeder operates 15 sec and is immediately re-energized; at 50 per cent meter flow, the feeder is on 15 sec and off 15 sec, and so on.

The motor runs continuously because the feeder is started and stopped by means of a belt shifter and a pair of drive and idler pulleys.

If the process has at least 15-min retention in the system, such as in a large mixing or coagulating basin, then a 60-sec or longer running time may be used, and a three-phase motor with magnetic starter may be substituted for the belt shifter and pulleys.

Pneumatic Instrumentation

Increasing use of pneumatic instrumentation has made possible *continuous* proportional pacing systems as illustrated in Fig. 10. Equipment for such an installation consists of:

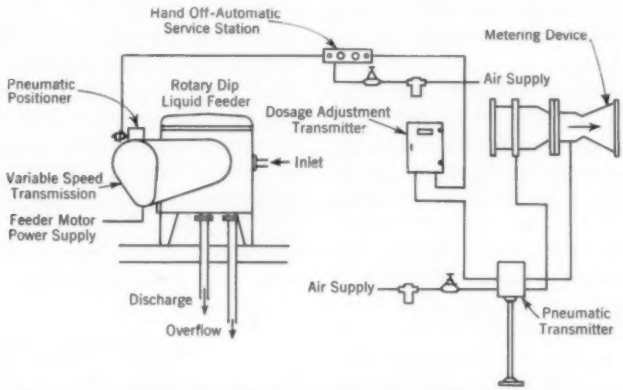


Fig. 10. Proportional Pacing With Pneumatic Transmitter

1. A differential producer—a venturi tube, for example
2. A pneumatic transmitter with an output of 3–15 psi, proportional to the flow through the differential producer
3. A dosage adjustment transmitter
4. A chemical feeder, liquid or dry, with pneumatically positioned variable-speed drive.

The flow of water through the venturi tube actuates the pneumatic transmitter to produce a variable air pressure output of 3–15 psig, proportional

to the water flow through the tube. This air pressure is linked to a dosage adjustment transmitter.

A ratio adjustment in the dosage transmitter enables the operator to change the chemical dosage rate. The retransmitted signal is sent to the pneumatic positioner on the chemical feeder (gas, liquid, or dry type). The output of the chemical feeder will continuously follow or pace the water flow rate.

Continuous pacing systems perform very satisfactorily on a limited-range proportioning system. The range of chemical feed (range of water flow times the range of chemical dosage) must be less than 10:1 unless special provisions are made for calibration or for occasional gear changes on the feeder or meter.

This limitation is due to the effect of cascading a group of linear instrument functions, all of which have decreasing accuracy as the feed rate decreases. The possible error of such a system increases as the chemical feeder range increases.

Summary

The foregoing illustrations represent the automation systems in most common use today. There are many other systems less widely used, and new ones are being developed.

Automatic proportional pacing and remote control are accepted practice in the water works field and automatic pH control systems are being used in increasing numbers. A few installations have been made using turbidity meters to pace chemical feeders. More will be built in the near future.

Automatic control of all chemicals used in water plants is possible and is rapidly becoming standard procedure. The present status of automation in water plants points to the completely automatic plant of the future. Automation of chemical feeding and handling is keeping pace with the industry.

Electrical Supervisory Controls at Vancouver, Wash.

Marvin H. Schroeder

A paper presented on May 3, 1957, at the Pacific Northwest Section, Tacoma, Wash., by Marvin H. Schroeder, Director of Utilities, Vancouver, Wash.

THE Vancouver, Wash., utilities department serves approximately 20 sq miles which has a population of 52,000 and about 15,000 services. Water is pumped from fourteen deep well turbine pumps grouped in three locations within the city. The wells deliver $\frac{2}{3}$ of the supply; the rest comes from gravity sources at Ellsworth Springs, 5 miles east of Vancouver. Fifteen booster pumps are used to raise the water from ground reservoirs to elevated storage. Four ground level reservoirs and four elevated tanks for water storage have a total capacity of 16,128,000 gal. Because of the wide dispersion of the pumps and reservoirs and to save on manpower, a complete automatic control system has been installed.

Automatic Control System

The system which requires no electronic equipment and uses no radio frequencies, operates from the reservoirs through a transmitter which controls the pumps, transmits the water level signal to the main station, and operates the recorder at that point. The transmitter, receiver, and recorder are on one separate circuit—an advantage in the event of a line power failure. Mercury is used in the main element, each $\frac{3}{4}$ in. indicating 1 ft of water elevation. Water level can be read at the transmitter at all times. Visible fuses are used to protect leased wires as well as the transmitting instrument. A 60-sec disc acts as a master timer for all equipment on the system and all controls are automatically reset. The receiver (Fig. 1) at the pumphouse is always in direct synchronization with the timer at the transmitter. Indications of any trouble at the receiver are transmitted to the main control house as a 5-sec alarm every 60 sec and trouble at the transmitter sounds a continuous alarm.

The plug-in arrangement is such that the position of operation of the pumps can be interchanged. For example, No. 4 pump can be operated in No. 1 position and so on. This keeps pumps in top condition, for, during the winter, idle pumps tend to gather moisture.

The delay relay prevents equipment from being damaged during operation. If a power failure occurs, this relay will not permit the pumps which were on the line at the time of failure to come back on immediately after restoration of power. Rather, booster pumps will start 2 min apart, allowing deep-well turbines time to go through a back spin (if not the ratchet type) and then come on the line 20 min apart.

At the main control station, recorders (Fig. 1) are installed to record water level, number of pumps running, which pump is in operation, trouble (if any), and where. Water levels are kept within 3 in. of the overflow line in all reservoirs and elevated tanks. Provision is also made for starting and stopping pumps at well and booster

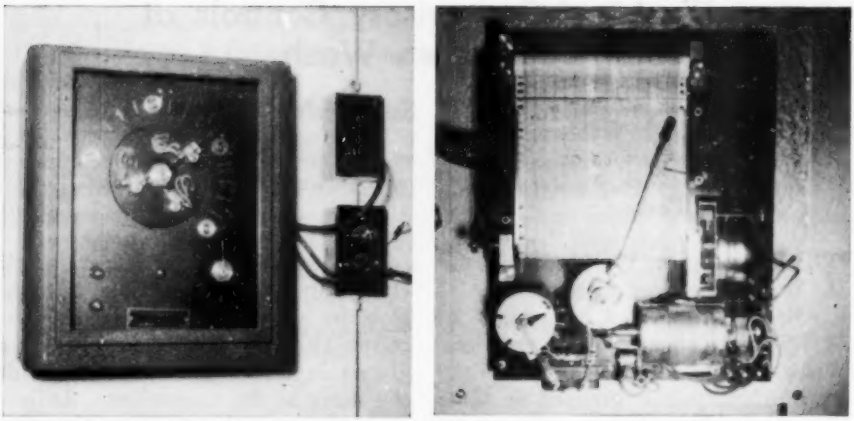


Fig. 1. Receiver and Recorder

Receiver, at left, is located in pumphouse, recorder at the main control station.

locations. For the future, the same starting and stopping controls are available for other locations, but it is felt that remote automatic control is better.

Each system has its own bell alarm and a red light located under the recorder. There is a test button for checking all the equipment of all stations. Each well has a timer to control running time and amount of water pumped. These controls automatically permit use of the whole gravity flow system before deep wells are used.

Protection, in the event of a complete power failure, is provided by a battery-operated alarm system. Secondary power is also provided. Hand-off automatic switches allow servicemen to check all equipment in a pump house without interference with the control system.

Personnel

Before installation of the system, five men were needed to check reservoirs and pumping stations; today, one man performs these duties as well as repairing meters and handling radio calls, and checking the control panel of the water system. He can tell at a glance water levels in all reservoirs and towers, and the number and location of the pumps operating.

Night watchmen are not used at either the water or treatment plant as these controls are installed in six sewage pumping stations, as well as at the treatment plant. At the second shift change at 11:00 PM, each operator places the main control panel in charge before he leaves. At the main control center, a house is occupied by one serviceman. He has an alarm nearby which he answers from 11:00 PM until 7:00 AM—two short rings for sewage, one long ring for water. If there is trouble at night he checks the main control board, determines the trouble, calls the serviceman, and explains where and what it is. He has a reminder that he sets for 30 min or more and, if repairs are not made by that time, the alarm is repeated.

This control system, in operation successfully for 4 years, has more than paid for itself.

Future Developments in the Greater Winnipeg Water District

Nathan S. Bubbis

A paper presented on July 19, 1957, at the Canadian Section Meeting, by Nathan S. Bubbis, Gen. Mgr., Greater Winnipeg Water & San. Dists., Winnipeg, Man., Canada.

ONE of the main characteristics of the present time is the tremendous and almost explosive growth of urban communities. Although this trend has been evident for about half a century, the acceleration which has taken place in the last 10 years has been staggering. This has been caused by the increase in population, the development and decentralization of industry, and the mechanization of farming, but basically the cause has been the automobile, which has created such congestion in the central areas of cities as to force business and industry to relocate in outlying subdivisions, while at the same time it has made suburbia possible.

The trend, which is now developing, however, more clearly in the United States but also in Canada, is the replacement of the familiar metropolitan area by what might be termed metropolitan regions. The old pattern of a central city surrounded by quiet suburbs is disappearing. The suburbs themselves are becoming bustling cities filled with industry, business, and shopping centers. These suburbs join and overlap until they are welded into an almost continuous urban area.

This development has confronted officials of all levels of government with tremendous problems, and water works officials are no exception. Historically, the great majority of water works utilities were built for a single community. As suburbs developed around the central core, in numerous cases changes were made to supply water to these areas with a view of the possibility of their eventual annexation. The rapid urban growth since the turn of the century resulted in the organization of water districts or metropolitan water utilities. Greater Winnipeg's experience in this regard is typical, and the Greater Winnipeg Water District, organized in 1913, was one of the first of such metropolitan authorities on the continent.

Water works publications contain numerous articles on the organization and operation of metropolitan water districts, including several good articles on the Greater Winnipeg Water District (*1–5*). The purpose of this article is to discuss some of the experiences of the Winnipeg district and to consider some of the problems with a view possibly of determining whether the usual metropolitan water authority as it now exists can serve changing requirements or whether changes will have to be made possibly along the lines of the Ontario Water Resources Commission.

Greater Winnipeg is composed of four cities, two towns, one village, and nine rural municipalities with a com-

bined population of approximately 410,000, and a total area of 261 sq miles. The rapid growth of the population since the war and the resulting problems of providing the required municipal services, such as sewers, sewage treatment, water, roads, and bridges, have given rise to a demand for a review of the existing method of organization of municipal government. As a result, the province of Manitoba, in September 1955, established a royal commission known as the Greater Winnipeg Investigating Commission to study this matter with a view to determining the desirability or otherwise establishing a more integrated development of the municipal government. A brief was recently submitted by the commissioners and the general manager of the corporation to this investigating commission; it dealt with the water works and sewerage aspects of the problem. This report discusses three general areas: water supply, finances, and treatment, particularly fluoridation.

In considering Winnipeg's water supply, it must be made clear that arrangements for delivery of water vary, depending on the type of area served: a municipality which is a member of the water district; a nonmember municipality; or an area outside greater Winnipeg. In addition, of course, there is also the question of estimating and planning for future requirements.

Supply to Members

The Greater Winnipeg Water District is an intermunicipal corporation, established by an act of the legislature dated Feb. 15, 1913, and made up of the cities of Winnipeg, St. Boniface, St. James, and East Kildonan, the towns of Transcona and Tuxedo, and the rural municipalities of Fort Garry, St. Vital, and West Kildonan. The district is responsible for conveying water in bulk and not under pressure from Shoal Lake 97 miles east to the individual member municipalities.

The Water District Act clearly specified that the district was to be the sole supplier of water to the municipalities and prohibits one municipality from supplying water to any person or corporation in any other municipality. But it does permit municipalities to use their pumping stations or distribution systems to convey Shoal Lake water under pressure to other municipalities by agreement (*2*). The municipalities themselves are responsible for the storing, treating where necessary, pumping, and distributing the water to their own residents.

Provision was also made in the Water District Act that when any municipality used more than 200,000 gpd * of water it could request, and the district had to construct, a separate supply line from the aqueduct to the boundary of that municipality so that it could undertake its own pumping. The first use of this provision was in 1953 by St. Vital (*3*), although inquiries are made from time to time by other municipalities, several of which are considering the construction of their own pumping stations in the future.

As long as there are fourteen separate municipalities with two possible additional ones responsible for providing water facilities, such as storage, treatment, and distribution, there will obviously be a considerable amount of duplication, the majority of which would be eliminated by a more integrated organization of these facilities. There is also a wide variation in the

* Gallons throughout this article refer to the Imperial gallon, which equals 1.2 US gal.

standard of the services being provided, a number of which are not adequate by modern standards.

Another very critical situation has developed in the matter of storage facilities. The water district is merely responsible for bringing water into the area to supply the maximum daily requirements. The maximum hourly requirements, however, are the responsibility of the individual municipality. In addition to this, as a precautionary measure, in view of the fact that a single pipeline supplies the whole area, each municipality should, as a matter of good engineering, provide storage of 2–3 days' capacity. Only the city of Winnipeg at the present time has storage facilities of anything like this amount. The other three municipalities who do their own pumping either have no storage facilities or at best only sufficient for several hours' supply.

An important consideration from the area point of view is that the present arrangement does not make for good planning. As an example, the city of Winnipeg is at present supplying five member municipalities and five nonmember municipalities with water, but there is no assurance that these municipalities will continue to be customers of the city of Winnipeg, as only the city of St. James has a specific undertaking to continue receiving water from Winnipeg until 1971. Consequently, Winnipeg has to make certain assumptions and is therefore under difficulty in planning its future requirements. In addition to this, Winnipeg naturally must think in terms of locating its future pumping stations and reservoirs within its own boundaries, but this may or may not be the best location for these facilities from the overall area point of view.

Supply to Nonmembers

The five nonmember municipalities are supplied with Shoal Lake water under somewhat complicated agreements. One multiparty agreement is between the district, the receiving nonmember municipality, and the other municipality whose distribution system is used to convey the water. A second separate agreement between the city of Winnipeg and the receiving municipality provides for pressure, storage, and certain treatment. Practically all of these agreements, however, stipulate that water will be supplied if and when available. No quantity nor pressure at the boundary is specified and nearly all have a provision that the agreements can be canceled on 60 days' notice, although undoubtedly this has more legal than practical significance, as it is hard to conceive of the water supply to any community being discontinued. Other than these agreements, however, the district is under no legal obligation to supply these nonmember municipalities with water, and the member municipalities are also under no obligation to reinforce their distribution facilities to deliver sufficient water to the nonmember municipalities. Consequently, these municipalities now find themselves with no assurance that their rapidly expanding water requirements can be met.

Recently, for the first time since the incorporation of the district in 1913, inquiries have been made by two of these municipalities concerning the possibility of their becoming members of the district. There is no provision for this in the present act, and in addition the financial aspects of their becoming members are extremely complicated.

It is, therefore, of interest that one of the two nonmember municipalities that had applied for membership in

the district has now applied to the city of Winnipeg for amalgamation. It is also interesting to note that if this municipality should be amalgamated with Winnipeg, then in accordance with the district's act, their entire area would become part of the water district area, although located a considerable distance from the present facilities. It might be further pointed out that while this might solve the problems of this one particular municipality, it would not relieve the difficulties of the others.

The duplication and other problems arising from the present organization of the water supply facilities in this area are somewhat similar to the conditions which prevailed in the Greater Toronto area prior to the establishment of the metropolitan district. It is quite obvious that a more integrated method of organization would result in greater simplicity and would provide an adequate supply of water to this community more economically.

Supply to Outside Areas

The greater Winnipeg district has recently received inquiries from a group of municipalties as to whether Shoal Lake water could be made available to them. These municipalities are located in what is known as the Pembina Triangle, which is an area located in the southern part of the province between the La Salle River and the United States boundary and extending from the Red River to approximately 60 miles west. This area is presently served by wells, and the supply is not satisfactory in terms of both quantity and quality. The terrain apparently does not lend itself to the erection of dams which would permit the impoundment of sufficient quantities of water, the quality of which would also be somewhat doubtful.

One of the first problems to be solved, of course, is to determine what the future requirements for water will be in this area as well as the economic feasibility of a pipeline from the Greater Winnipeg area as compared with other possible sources, such as the Red River. The provincial government has engaged consultants to investigate this problem, but the district, once the quantity of water required is determined, will undoubtedly be asked to indicate whether it is in a position to undertake the supply and at what cost.

The town of Selkirk, located some 25 miles north of the city, is also investigating an alternative source of supply to its present, very hard well water. It is understood that consideration is being given to the possibility of asking the district to supply it with water.

With the construction of the trans-Canada highway, which roughly parallels the district's aqueduct, east of the Ontario border, a number of small developments are being constructed along this route, and inquiries are being received for a supply of water. One such request was granted last year in the town of East Braintree. The problem here, however, is that the district is primarily a wholesaler and up to the present has not had occasion and is somewhat reluctant to undertake the supply of water to individual private customers. Since most of these latter requests come from unorganized territory, it is difficult to see how this problem can be dealt with other than supplying this water to individual customers.

Estimating and Planning

One of the major problems with which every water utility is confronted is first determining what its future

water requirements will be and then planning and constructing its facilities so that it will always in a position to render adequate service to the community it serves. In this connection, it should be pointed out that those who planned the original work (*1*) did an excellent job. While their original predictions of population growth were not realized due, among other factors, to the construction of the Panama Canal, the facilities which were built did, however, give this community an assured and adequate supply of water for many years. No additions were made until

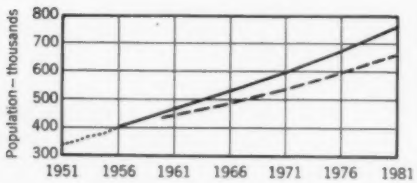


Fig. 1. Estimated Population of Greater Winnipeg

Solid line indicates the prediction of the Metropolitan Planning Commission; the dashes indicate the 1955 prediction by the district for the Gordon Commission. Dots show actual 1951–56 growth, based on 1956 census figures.

1950, when the booster pumping station was built. As originally planned, a second aqueduct will be required by about 1960. Plans for the construction are now underway, and it is expected that contracts will be let by the spring of 1959. This will complete the work originally planned in 1913.

The district's engineers, however, are already making plans for future requirements. Figure 1 illustrates some of the recent population estimates made. The Gordon Commission has predicted a very great increase in population by 1980. In submissions made to this Gordon Commission, population estimates were made by both the district and the provincial government, and results were very close. These estimates were made, however, before the 1956 census figures were available. An estimate made recently by the Greater Winnipeg Metropolitan Planning Commission, also shown on Fig. 1, was based on the 1956 census figures. The planning commission in a recent report states that this area can expect an increase in population within the next 10 years of about 120,000.

Estimates have therefore been made of future water requirements. These are shown on Fig. 2. From this chart, it is clear that an additional source of supply will be required by approximately 1973, although this would be hastened by a year or two if the district were to supply water to the towns in the Pembina Triangle.

Studies will also have to be made to determine what form this additional supply might take. There are several possibilities. In 1913 provision was made for a second aqueduct paralleling the present aqueduct, although this would require pumping. A second possible alternative, however, is the construction of a pipeline which would convey water under pressure from the Winnipeg River, probably from near Seven Sisters, and parallel to the highway to the Red River at St. Andrews Locks, and thence to Winnipeg. A spur could be taken off to serve the town of Selkirk, and other communities could also be served along the line.

A pipeline would have certain advantages over a second aqueduct. It could conceivably provide the peak load requirements during the summer by pumping so arranged as to use off-peak power close to its source of supply,

with the water moving from Seven Sisters into Winnipeg. During average conditions the water could be supplied to these communities from either Winnipeg or from Seven Sisters, depending on economic and hydraulic considerations. It would also provide a second pipeline located some considerable distance away from the original line.

A third possibility might be the construction of larger reservoirs to iron out peak demands.

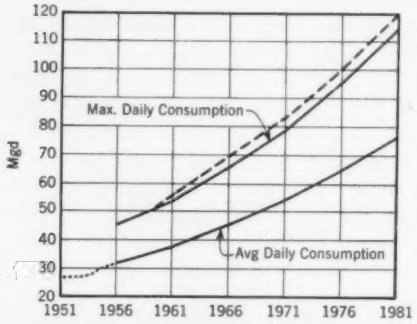


Fig. 2. Estimated Water Consumption for Winnipeg District

Dashes indicate estimated maximum daily consumption including the proposed Red River Valley requirements; dots indicate actual average daily consumption for 1951–56.

Financial Problems

One of the first problems which always arises in any utility is the development of a rate structure, and anyone who has had anything to do with rates is aware of the fact that it is extremely difficult to try to establish a system which is both equitable and administratively simple. There are also probably as many different theories and philosophies on rate structures as there are people who are designing them.

For example, in any utility such as the water district, it must be decided whether the revenue should be derived solely from the sale of water or if some of the revenue should come from taxation. A review of various rate structures of different metropolitan utilities reveals that these vary from one extreme to the other. For example, both the Greater Vancouver Water District and the Greater Victoria Water District derive their revenues solely from the sale of water, and no taxation is imposed. The Metropolitan Water District of Southern California goes almost to the other extreme, when for the period 1929–56 the revenue derived from taxation was $253,662,000, compared with $30,131,000 obtained from the sale of water.

There are, of course, arguments on both sides. Those who believe in obtaining all the revenue from the sale of water maintain that the person actually using the commodity should pay the whole charge. This is very similar to the rate structure used by electrical utilities, with perhaps the exception that electric utility rates nearly always have a provision for readiness to serve, usually in the form of a connected load or demand charge, whereas this feature is practically unknown in water utility rates, although it has been imposed recently in some cases for air conditioning.

Those who advocate that some of the revenue be obtained from taxation maintain that the very fact that a water utility is established in an area immediately enhances the value of the land. Further, even if this land is not used but is held speculatively for future development, the water utility receives no immediate revenue from water sale but has nevertheless made considerable capital expenditures for pipelines and other structures and is ready and able to provide service.

The Winnipeg district, therefore, in its original act, provided for a combina-

tion of both methods of charges. It was intended that the interest and sinking fund requirements be met by an annual tax upon all of the lands, exclusive of improvements, within the district. Provision was also made for a direct charge for water sold at the same rate for all municipalities. The intention also was that this rate, as nearly as possible, was to be based on the cost of maintenance, operation, and management of the utility. Originally, the rate was set at 1¼ cents per 1,000 gal, but it was soon found that as a result of the relatively small amount of water sold, the land tax was extremely high and that it would be necessary to increase the direct charge made for water. Consequently, an amendment to the act was secured raising and limiting the rate to 5 cents per 1,000 gal. The annual levy has been reduced steadily from $1,242,000, in 1922 to $560,000 in 1951 and has remained at that level to date.

It should, however, be pointed out that although the original intention was that all of the land in the district which would ultimately be served by water and which had increased in value as a result of the construction of the aqueduct should be subject to the levy, the benefits of this method were largely lost by the insertion in the act of a clause which permitted areas within municipalities to be withdrawn from the water district area. All the municipalities, with the exception of the city of Winnipeg, used this means of withdrawing large sections of their land from the area. The net result of this was virtually to defeat the purpose for which the levy was intended, since the lands which remained in the water district area virtually became those areas which were actually served by water. In addition, there was a continual administrative problem of bringing small tracts of land into the district. This required a bylaw, and it also had the effect of leaving large islands and isolated peninsulas of land which were not in the water district. In the last 5 or 6 years the commissioners have adopted a policy of insisting that only large areas of land be incorporated and that, wherever possible, these be consolidated into a continuous area. At present just half of the 123 sq miles comprising the area of the member municipalities is included in the area.

The district will soon have to give consideration, however, to a review of the method of collecting revenue by means of the levy (Fig. 3). An additional aqueduct from Deacon will have to be constructed very soon (*1*). This aqueduct will be required primarily to serve the areas which will be developed in the next 10–15 years. It therefore does not appear to be quite equitable to levy the cost of this additional aqueduct on those who have already paid for most of the costs of the original works and who are already being served more or less adequately at the present time. It may therefore be desirable to have the act amended so that all areas which will eventually be served by this additional aqueduct will be required to pay for the cost and therefore be included in the water district as of the time of the aqueduct's construction.

Another interesting provision of the Water District Act is the one for the use of mains of one municipality to supply another municipality (*2*). It is under this provision that Winnipeg supplies five member municipalities with water and until recently, St. Boniface had supplied the municipality of St. Vital. The act further specifies that for the use of these mains, the cities of Winnipeg and St. Boniface shall receive a rate of 5 cents per 1,000 gal.

There is apparently no relationship between this rate and the actual size or length of the transmitting mains involved. It will also be apparent that if the district receives 5 cents per 1,000 gal for the sale of water and then has to pay 5 cents for the use of the municipality's mains, one cancels the other

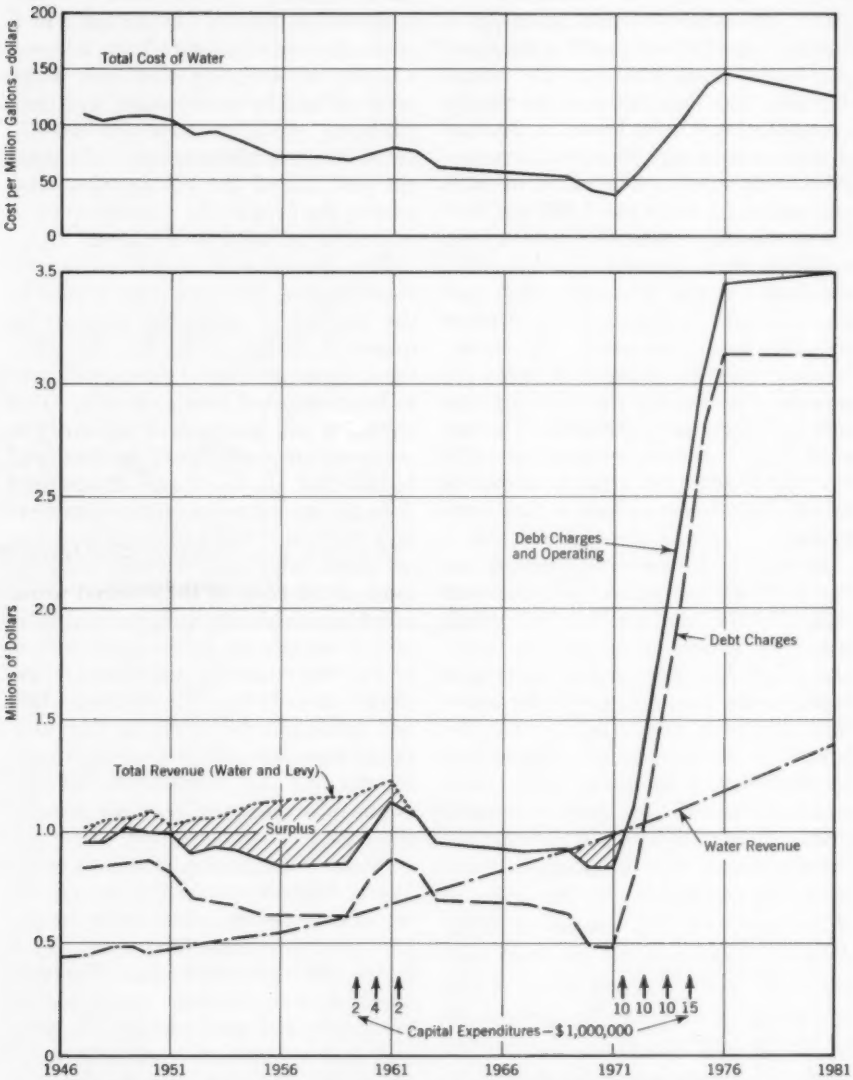


Fig. 3. Revenues and Expenditures for Winnipeg District, 1946–81

Water revenue is figured on rate of 5 cents per 1,000 gal.

and there is no net revenue derived from the sale of this water.

There is another section of the act which might possibly be interpreted in such a fashion as to enable the water district to recover this 5 cents or rather to pass it along to the municipalities who do not operate their own pumping stations, as is now done in the case of nonmember municipalities. This section of the act is being given very close study at this time.

The act also provides that the corporation may sell, supply, and deliver water to any person, firm, or corporation outside the district at a price which may be agreed upon, and for the purpose of so supplying and delivering water, the corporation may use the water distribution systems of any municipality so far as the same extends or is required upon terms to be agreed upon between the corporation and the municipality, or in the case of disagreement, upon terms to be determined by the Municipal and Public Utility Board. The district here too has followed the practice of paying the municipality concerned at the rate of 5 cents per 1,000 gal of water.

It should be noted that in all sections of the act, the water which the district delivers is always referred to as being conveyed and delivered not under pressure. It is perfectly obvious, however, that the water can only be delivered and utilized under pressure. While no specific provision is made for this in the act, the arrangement in practice has been that the city of Winnipeg has, by special agreement, agreed to store and deliver this water under pressure and for this has established a rate of charges. At the present time, the city is reviewing these charges.

While these agreements for pressure are actually between the receiving municipality and the city of Winnipeg, the district nevertheless has an indirect interest in them. If the rates charged for pressure and for the use of mains reach a certain point, then it may conceivably become more economical for one of the member municipalities to demand from the district that they construct a supply main from the aqueduct to their boundary and erect their own pumping station, as was done recently by St. Vital. This, in effect, would be a case of the duplication of facilities and in all probability would not provide the most economical arrangement from the overall point of view.

As has been mentioned earlier, there is a clear division of responsibility between the district and the other municipalities. It is obvious that with the expansion which is expected to take place in the next 10–15 years, a considerable amount of capital expenditures will have to be undertaken (Fig. 3). Table 1 indicates the extent of these capital expenditures which it is estimated will be required between 1956 and 1981. These are classified as those which will have to be undertaken by the district and those which will have to be undertaken by the individual municipalities.

The city of Winnipeg, in the last 10 years, has done considerable financing of water facilities, without experiencing any degree of difficulty as long as it has been able to keep these amounts within reasonable proportions. Most of the other municipalities, however, with one or two exceptions, have had great difficulties in financing local improvements in new areas, so much so that the only method in many cases, in order to provide for the carrying out of their improvements, has been to turn the land over to private contractors to develop the areas. In certain other mu-

nicipalities it has been virtually impossible to achieve any development at all. Some recent legislation by the Manitoba government whereby debenture issues may be taken up by the province under certain conditions may relieve this condition to some degree.

The net result of the above has been that many of the municipalities have not been able either to construct, maintain, or extend their water facilities adequately.

The water district in recent years has done no financing other than some relatively minor refinancing and has enjoyed excellent credit. Provided that favorable economic conditions continue, it is not anticipated that any great difficulty should be encountered in financing projects required by the district, although it should be pointed out that a very serious problem may arise as a result of a provision in the act which states:

1. Except as hereinafter provided, no bylaw of the corporation for the borrowing of money by the issue of debentures under Section 42 shall be valid or acted upon until approved by a by-law of the city of Winnipeg that has been first submitted to the ratepayers of that city in accordance with the provisions of the Winnipeg Charter 1940, respecting the submission of by-laws for the borrowing of money.

2. By-laws for the borrowing of money required for betterments, replacement, extensions, or additions to the works or plant of the corporation, not exceeding the sum of $200,000 in any one year, need not be approved as provided in Subsection (1), and the board may enact such by-laws as it may deem expedient for such purposes.

Recently the city of Winnipeg has experienced some difficulty in having money bylaws approved by the rate payers. An expenditure of about $8,000,000 will have to be made before 1961 by the water district for a second aqueduct between Deacon and Winnipeg. Since this will be required principally to serve the municipalities around Winnipeg, it might conceivably happen that the ratepayers of the city will turn this expenditure down.

It might also be stated that there is a definite contradiction between this section of the act and one which states that the corporation shall forthwith construct a separate supply main to any municipality whose consumption has reached a quantity of 200,000 gpd.

TABLE 1

Estimated Population and Capital Expenditures for Water Facilities in Winnipeg Area*

Year	Population Served	Water Consumption—*mgd*		Capital Expenditures†—$1,000,000	
		Avg.	Max.	District	Municipal
1956	413,000	31.6	45.5	7.9	12.8
1961	465,000	37.2	54.0		10.2
1966	530,000	45.0	65.6		9.2
1971	595,000	53.5	78.6	45.0	10.9
1976	677,000	64.3	95.0		11.1
1981	760,000	76.0	114.0		
Totals				52.9	54.2

* Based on April 1957 construction costs.
† For 5-year period beginning with year shown.

It could conceivably happen that if such a request were made and the debentures required exceeded $200,000, a by-law would have to be approved by the Winnipeg taxpayers. If this bylaw were to be defeated then the district would be in a position where it could not carry out its obligations under this particular section of the act. Another anomaly is that Winnipeg is not required to have money bylaws for water works facilities approved by the ratepayers. The sanitary district only requires the approval of the Municipal and Public Utility Board. Consideration is being given now to a question of making certain amendments to the act to overcome this difficulty.

It might also be mentioned that a considerable amount of the capital expenditure for water works purposes which will have to be spent by Winnipeg will be for the extension of feeder mains which will primarily be required to convey water to the municipalities which the city now serves. While this is undoubtedly good engineering, it should, however, be coordinated with a similar program in the neighboring municipalities to form part of an area plan for water distribution. Similarly, feeder mains should also be constructed of a proper size in the next ring of municipalities which surround the city proper. It is understandable, however, that the municipalities concerned, particularly those with financial problems, are most reluctant to embark on such a scheme. In any case, there is no provision for overall control.

Treatment Problems

In the division of responsibility between the district and the receiving municipalities, the matter of water treatment has always been considered to be the responsibility of the individual municipalities, since the district was merely delivering Shoal Lake water in bulk to the Greater Winnipeg area. As a result, there is considerable difference in the degree of treatment given the water in the various municipalities, ranging from full chlorination and algae control in Winnipeg to, until recently in one municipality, no treatment whatsoever. There is probably also a considerable need for booster chlorination in the outlying municipalities.

Even in the city of Winnipeg, however, difficulties were encountered in trying to treat the water for algae control during hot summer months. This difficulty resulted chiefly from the fact that the city had reservoirs at only one of its two pumping stations. It wasn't possible to treat the water at the fire service water works. At the McPhillips Street Station, however, algae control was carried out by means of copper sulfate and also by free residual chlorination. In an attempt to provide a measure of treatment for algae control to all of the water supplied to the area, it was decided several years ago to experiment with the use of copper sulfate at the intake at Indian Bay. Since it takes approximately 48 hr for the water to travel from the intake to Winnipeg, this proved quite successful. Accordingly the district installed a copper sulfate feeder 2 years ago and has been applying this chemical each summer as required, with a resulting improvement in the quality of the water.

The Winnipeg area has not been immune from the fight for fluoridation. On several occasions prior to 1955 the city council gave consideration to the fluoridation of the city's water supply. Since Winnipeg conveys water to five member municipalities and five non-

member municipalities through its distribution system, however, this meant that these other municipalities would also be receiving fluoridated water. The city solicitor, on investigating, apparently found that this could not be done without the consent of all of the other municipalities, which was not forthcoming. St. Boniface and St. Vital, who each supply their own requirements, had also given consideration to fluoridating their supply. In both of these cases there were no legal impediments to their doing so.

The city of Winnipeg then approached the district and inquired whether it would undertake fluoridation. The district's act was originally set up to supply raw water in bulk and not under pressure to the various municipalities. The district solicitor therefore advised that, particularly in view of the experience in metropolitan Toronto and the province of New Brunswick, he felt it would be necessary for the district to have its act amended to permit fluoridation. From an engineering standpoint, there were some advantages in having the district undertake fluoridation, since this required only one installation as against five and ultimately seven installations if fluoridation was to be carried out by the four municipalities who operate pumping stations.

As a result, a bill was introduced into the Manitoba legislature at its 1956 session to amend the district's act to permit it to fluoridate Greater Winnipeg's supply. The conditions under which the district was empowered to commence fluoridation are: "The Corporation shall not take any action under the authority granted by subsection (2)," making the introduction of fluorides subject to the Public Health Act, "unless a resolution approving such action by the corporation is passed by the Council of each of at least five municipalities that are member municipalities on the coming into force of this act, and the total combined population of which, as shown by the latest census, comprises not less than 85 per cent of the total combined population, as shown by the latest census, of all the municipalities that are member municipalities on the coming into force of this act."

Another section, inserted at the insistence of the district, reads: "When 5 years have elapsed from the time the corporation first introduces fluorides into the water under subsection (2), if a resolution requiring the corporation to cease taking such action is passed by the council of each of at least four municipalities that, on the date the last of such resolutions is passed, are member municipalities and the total combined population of which, as shown by the latest census, comprises not less than 20 per cent of the total combined population as shown by the latest census, of all the municipalities that are member municipalities on that date, the corporation shall forthwith cease introducing fluorides into the water under subsection (2)." It was originally requested, however, that this section be worded to require action by five municipalities, with a combined population of at least 50 per cent.

The district then asked each member municipality to state whether it desired to have its water fluoridated. Ultimately six of the nine municipalities, or a combined population of 88.69 per cent indicated that they were in favor of fluoridation. The following resolution was then adopted by the administration board on Jun. 28, 1956: "That the district proceed with fluoridation and that the commissioners be instructed to take the necessary steps to carry out

this decision, including the filing of the necessary information with the provincial government and the calling of tenders for the necessary equipment."

The district then called for tenders for a gravimetric, loss-in-weight feeder, together with the necessary bulk storage hopper, bucket elevator, and controls. The equipment was installed by district forces, thoroughly tested, and was placed in regular operation on Dec. 28, 1956.

The district was able to negotiate a contract for a year's supply of sodium silicofluoride from a local chemical supplier. This material is added to the water in amounts proportional to the water flow so as always to maintain a fluoride concentration of 1.0 ppm. Capital expenditures for the installation to the end of 1956 totaled approximately $9,000.

In view of the criticism and agitation that is continuously going on against fluoridation and in view of the fact that the fluoridating equipment is located so far away from Winnipeg, the district thought that it might be advisable to consider additional safety measures, purely on a precautionary basis. Accordingly, the district asked for quotations on the installation of a fluoride concentration recorder which will be set to trigger an alarm if amounts of fluoride in excess of 1.5 ppm should find their way into the water supply. This equipment should be received and installed shortly. While this type of apparatus has been used in at least one other installation for the purposes of controlling the feeding of fluoride chemical, in Winnipeg it will merely act as an additional monitor.

Conclusions

The Winnipeg water district has now been in operation for over 38 years, and it speaks well for the people who framed the original act that it has enabled the Greater Winnipeg area to receive an adequate potable water supply at an economical price for all these years. Nevertheless, with the passage of time, conditions alter, and this in turn makes it necessary that changes be made in both the acts and the various methods of organization and operation. With the rapid growth of population and the expansion and development of areas surrounding Winnipeg, it has become clear, as already mentioned, that there is a need for reviewing existing conditions with a view of making sure that the municipal government and various public utilities will be able to continue to provide adequate service. The conclusions of the brief which was submitted to the Greater Winnipeg Investigating Commission state in part:

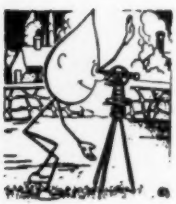
> In considering the whole question of metropolitan services, your Commission may wish to consider the following alternatives to the present method of organization of the water and sewerage services in the Greater Winnipeg area: . . . If complete amalgamation of most, if not all, of the sixteen municipalities in this area into a single unit is proposed, then the water works and sewerage facilities would almost definitely be amalgamated automatically. . . .
>
> If [this] is not deemed to be either desirable or feasible, then it might still be possible to amalgamate the water supply and sewage treatment facilities of the districts with the water storage, water treatment, water distribution, and sewerage facilities of the various municipalities and the services being performed, into one metropolitan department. . . .
>
> If neither . . . is deemed to be either desirable or feasible, a third possibility would be to extend the scope of the Greater Winnipeg Water and Sanitary Districts along the lines of the Department of Works of Metropolitan Toronto.

In the case of water, the construction, maintenance, and operation of the pumping stations and feeder mains would be added to and become the responsibility of the Greater Winnipeg Water District. The construction and maintenance of all trunk sewers would be added to and become the responsibility of the Greater Winnipeg Sanitary District.

It would appear that a more integrated reorganization of the whole area by either amalgamation or metropolitan development would assist materially in permitting the development of adequate water and sewer facilities on a more economical basis."

Canada's population, presently approximately 16,500,000, is expected to grow to at least 28,000,000 and possibly 30,000,000 by 1980; two-thirds or more of this increase will be in the large metropolitan areas but less than 5 per cent within the central cities of these areas. Greater Winnipeg is no exception, and as already mentioned, indications are that its population will increase by about 350,000 by 1980 and that 120,000 of it is expected to be in the next 10 years.

There are undoubtedly formidable problems, but surely they are no greater than the ones faced by the city fathers between 1905 and 1919. If the same vision, courage, and breadth of point of view which guided its predecessors is used and if the method of organization is amended to bring it up to date, there should be no reason why this area, which has been so well served by its water utility, should not continue to benefit by having an assured, adequate supply of wholesome potable water.



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Honolulu Water Supply

Edward J. Morgan

A paper presented on May 13, 1957, at the Annual Conference, Atlantic City, N.J., by Edward J. Morgan, Mgr. & Chief Engr., Board of Water Supply, Honolulu, T.H.

QUITE aside from its reputation as a world-famed tourist mecca, Honolulu has a water system rich in historical importance and unique in its operations. From its humble beginning early in the nineteenth century under the Hawaiian monarchy, the story of water development in Honolulu is a dramatic sequence of events leading up to the modern and highly efficient system of today.

Honolulu is the capital of the Territory of Hawaii. It is located on the island of Oahu, the third largest of the eight principal islands comprising the Hawaiian Islands. Its latitude is 20° 19′ North, approximately that of Mexico City, and the longitude is 157° 52′ West, approximately that of Kodiak, Alaska. In terms of nautical miles it is 2,090 miles from San Francisco, 2,230 miles from Los Angeles, 4,220 miles from Sydney, and 3,394 miles from Yokohama. By reason of its strategic location, Honolulu is truly the "Crossroads of the Pacific."

Geologically speaking, the island of Oahu is relatively young. It is believed that the formation of the island probably began in the Cretaceous period, 60,000,000 years ago when two adjacent volcanic domes commenced to lay down successive layers of lava flows on the ocean floor (Fig. 1). This gradual building up of lava eventually resulted in the emergence of two cones above the surface of the ocean. After the appearance of the westernmost cone (Waianae) above sea level, lava from the eastern cone (Koolau) flowed against the earlier western cone. This merging of the outpouring lava from the two cones, followed by many centuries of erosion, resulted in what is now the island of Oahu.

Honolulu is blessed with a semi-tropical climate. The highest temperature recorded is 88°F and the lowest 56°F, the annual mean being about 75°F. While precipitation within the city proper is far from plentiful, rainfall in the watershed area, particularly in that portion which is located outside of the city limits where readings of 400 in. per year are not uncommon, is sufficient to provide enough water for the island for any probable future requirement provided a reasonable degree of conservation is practiced. Typhoons, hurricanes, tornadoes, and disastrous earthquakes are not known in the Hawaiian Islands, although active volcanic activity still persists on the island of Hawaii, the largest of the group.

The population of the Hawaiian Islands now exceeds 500,000; about 75 per cent live on the 604 sq miles comprising the island of Oahu. Honolulu's population is slightly in excess of 285,000, exclusive of military personnel

and dependents. The young and vigorous characteristic of the inhabitants has been reflected in the sharp rise in population during the past several years.

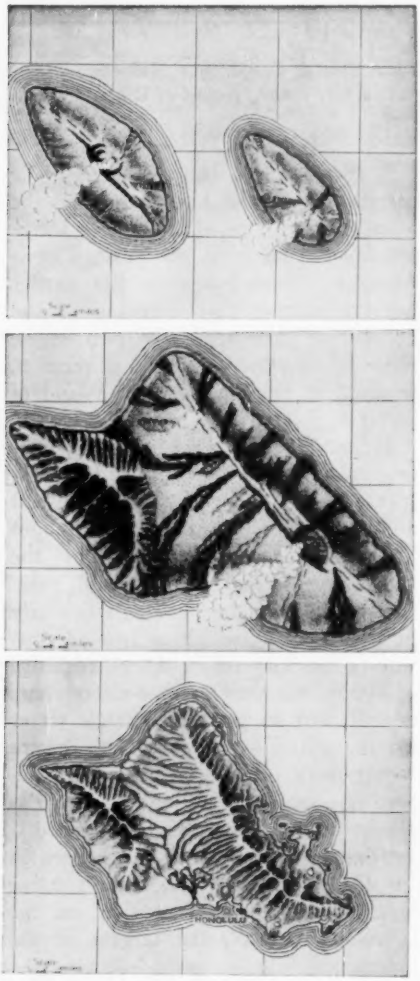

Fig. 1. Geological Formation of Oahu

The island is pictured as two volcanic cones emerge from the sea (top); during the period of erosion and merging (middle); and as it presently appears (bottom). The scale is approximately 20 miles per inch.

There is every indication that the city will become a thriving metropolis of well over 400,000 by 1980.

Historical Background

The Honolulu public water system is one of the oldest in the country west of the Mississippi River. Prior to 1822, when the first shallow well was dug, the Polynesian inhabitants depended entirely upon surface streams and springs for their water supply. In 1848 the first unit of a government-owned and operated water system was installed in the form of a water tank and piping system primarily to serve whaling ships. From this humble beginning and for the next 30 years the Honolulu water system grew steadily, beset with perplexing problems on potability, palatability, and adequacy of supply.

The year 1879 was a most memorable one in the entire history of the development of Oahu and Honolulu. In this year artesian water was discovered under the coastal cap rock on the leeward side of the island. The first artesian well, of a total depth of 240 ft, was drilled on the shores of Pearl Harbor, just outside of the Honolulu District boundary. About a year later the first artesian well was dug in the city. Fresh water was struck at a depth of 273 ft and rose to an elevation of 42 ft above sea level, thereby establishing the historical "original" artesian head in the Honolulu District. It was not until 1895, however, that the public water system began to furnish water from artesian wells.

The discovery of artesian water in 1879, together with the then rapidly increasing need for vast quantities of water for agricultural and domestic purposes, set the stage for the subsequent digging of hundreds of wells in many areas of the island. The result

was a steady depletion of the accumulated artesian supply and consequent deterioration of many wells due to sea water intrusion. With a number of its wells endangered by such encroachment

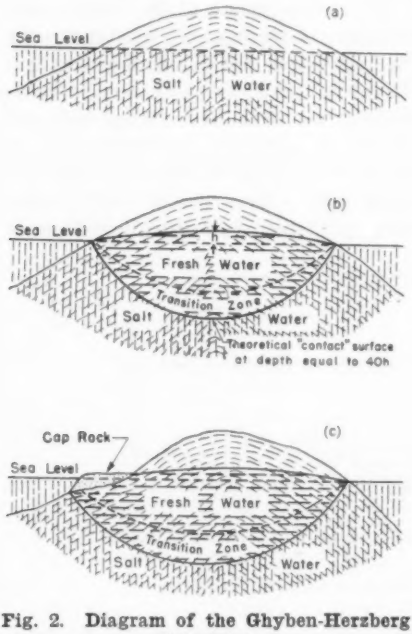

Fig. 2. Diagram of the Ghyben-Herzberg Principles

Fig. 2a depicts a permeable island under a condition of no rainfall. Fig. 2b shows the results of rain seeping through the rock of a permeable island and forming a "lens" on top of the heavier salt water. The height of fresh water above sea level is represented by h, *with the transition to salt water occurring at a point below sea level equal to about 40*h. *Fig. 2c shows the same condition existing under an island such as Oahu, with a cap rock along portions of the coast.*

the Honolulu Board of Water Supply, which was created by the legislature in 1929 to meet the critical water problem confronting the city, met the challenge by carrying out a vigorous metering program and an artesian well control program made possible by the legislature. Water distribution facilities were greatly improved, and the final phase was the installation of underground pumping stations in place of artesian wells. Located as far inland as practicable these stations pump water from sumps and sea level development tunnels located just beneath the free water table. The first of these stations was built in 1936, a total of three being in operation at present. The introduction of underground pumping stations in Honolulu was unquestionably the second most important development in the history of the Honolulu water system, the first being, of course, the discovery and development of artesian water.

Underground Sources

The various conditions that influence the occurrence of ground water in Hawaii are largely different from those throughout the United States mainland. In order to derive a better understanding of Hawaii's ground water development, it would be best to discuss briefly the geology and hydrology involved in the formation and retention of underground water bodies in the island rock masses.

Needless to say, all of the surface and ground water supplies in the islands are dependent upon rainfall for replenishment. Insofar as ground water is concerned, reference is made to Fig. 2 to describe hypothetically the manner in which it would originate in an ideal, simple island formed by volcanic action as in the case of the Hawaiian Islands.

Volcanic islands built up in this manner consist almost entirely of highly permeable rock. Figure 2a shows an ideal permeable island under a condition of no rainfall. Since the

island is permeable, the rock mass located below sea level is saturated with sea water. When such an island is in a rain belt, however, as shown in Fig. 2b, the infiltrating rain water passes downward through the pervious rock until it comes to rest on top of the salt water. Since fresh water is lighter than salt water, it accumulates and spreads on top of the salt water. At the coastline of the island the fresh water tends to escape to sea as coastal springs. As the percolating rain water continues to add to the fresh-water body, a dome is built up which extends laterally to the sea in all directions. This mounding up of the fresh water is due to a retardation of flow as it moves laterally in overcoming friction in the rock fissures.

Since, according to the principle of Archimides, a floating object displaces an amount of water equal to its own weight, the fresh water in the islands presses downward against the salt water to form a body extending some distance below sea level. Static equilibrium is attained when the depth of fresh water and brackish water below sea level is about 40 times its height above sea level. This is due to the fact that salt water is $\frac{41}{40}$ times as heavy as fresh water. It should be emphasized that such static equilibrium is only an ideal condition which probably never occurs. Actually, the hydrologic conditions described above are dynamic and only tend to approach static equilibrium.

The phenomenon of the double convex lens of fresh water existing in the 40:1 ratio is based on the Ghyben-Herzberg principle. This remarkable relationship was first recognized and described, apparently independently, by Badon Ghyben of Holland in 1889 and Herzberg of Germany in 1901. Since then geologists and hydrologists have referred to the lens as the Ghyben-Herzberg lens. If, as shown in Fig. 2c, the products of erosion form an impervious caprock along portions of the seacoast of such an island, the escape of fresh water is impeded and a thickening of the lens results.

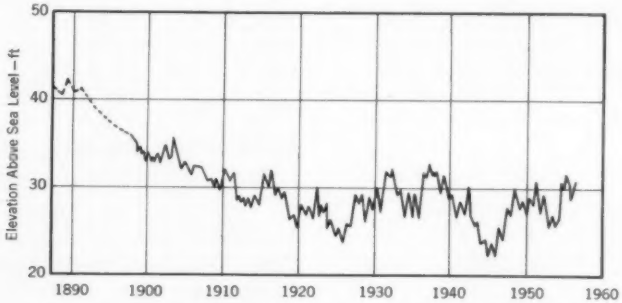

Fig. 3. Record of Artesian Level in Central Honolulu

The city of Honolulu and Pearl Harbor are built on a prism-shaped cap rock, which extends for about 25 miles along the shoreline of the city of Honolulu. The top of the cap rock is the coastal plain on which the city is built. It extends several miles seaward and is about 1,000 ft thick near the shoreline.

As previously mentioned, the discovery of artesian water in 1879 was

followed by the drilling of a large number of wells through the cap rock where artesian pressure is sufficient to produce flowing or easily pumped wells. There is a total of 25 artesian wells in the Honolulu water system at the present time, the total output being approximately 13 mgd, or slightly more than one-third of the total quantity of water produced for the city from all sources.

Underground Pumping Stations

As mentioned earlier the original head of fresh water in the central part the effect on artesian wells due to the shrinkage of the Ghyben-Herzberg lens.

Faced with the constant threat of salt intrusion it was felt that, because the fresh water body is thicker as one goes inland, water developments located some distance from the sea would be less vulnerable to saline encroachment. This simple deduction inspired the Honolulu Board of Water Supply eventually to perfect the design of underground pumping stations (Fig. 4) which are now referred to as basal stations. A section of such an installation

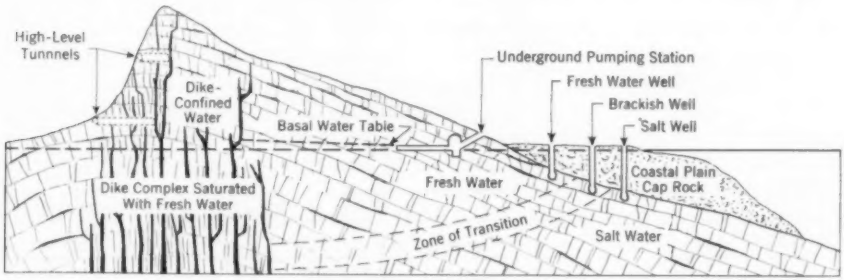

Fig. 4. Geologic-Hydrologic Section of Honolulu Area

Shown above is a diagram of the types of water sources discussed in the text: the artesian wells, the underground pumping station, and the high-level or "perched" sources.

Honolulu area was about 42 ft when the first artesian well was drilled in 1880. Since, according to the Ghyben-Herzberg principle, the depth of fresh water was theoretically more than 1,600 ft below sea level, several wells drilled to depths of greater than 1,000 ft yielded water of high quality. Heavy draft from an ever increasing number of wells, however, resulted in such depletion of the ground water body that many of the deeper coastal wells became salty or brackish. Figure 3 represents a historical record of the artesian level in central Honolulu, while Fig. 4 is a cross-section showing in is shown in Fig. 5, the principal components being a 30-deg inclined shaft, pump room, sump, and development tunnel. The 30-deg inclined shaft is preferred because of maintenance advantages, in addition to the fact that such a shaft would locate the pumps at a distance from impervious valley fills that would ordinarily restrict the effective drawdown area. With the station portal located at an elevation of about 160 ft, the inclined shaft leads to the sump and development tunnel near sea level.

In laying out the horizontal development tunnel it is important that it be

in the direction from which the lava came as the greatest yield is in this direction. A principal problem here is to have sufficient pumping capacity installed during construction to keep the tunnel unwatered.

Representative stations have tunnel lengths up to 1,200 ft, but in some locations, particularly where the rock is extremely porous and lava tubes are present, sufficient water has been developed in the sump itself, with little or no tunnel. These tunnels are often called "skimming tunnels," because water is taken from the top of the fresh water lens in somewhat the same manner as cream is skimmed from milk.

A good station of this type yields from 15 to 30 mgd of water. The combined yield from Honolulu's three such stations averages about 22 mgd, whereas the supply from the older well stations averages 16 mgd. The city of Honolulu uses an average of 38 mgd, with a summer peak of 50 mgd.

Mountain Gravity Sources

In spite of the fact that over 90 per cent of the city's water supply is obtained from deep underground sources, the remaining 10 per cent or so which comes from "perched," or high-level, sources constitutes an exceedingly valuable supply. Perched water, as the name implies, is water confined by intrusive rocks in dike-walled compartments (Fig. 4) or perched on relatively impervious material such as tuff, soil, ash, or alluvial beds. In Honolulu, bodies of perched water are located high in the valleys back of the city.

In dike water development, for each lava flow there was an avenue through which the molten lava was forced to the surface. The lava in these avenues was under great pressure and upon cooling became dikes of exceedingly dense rock.

Many dikes are interconnected so as to form watertight compartments which, in areas of sufficient rainfall, are filled

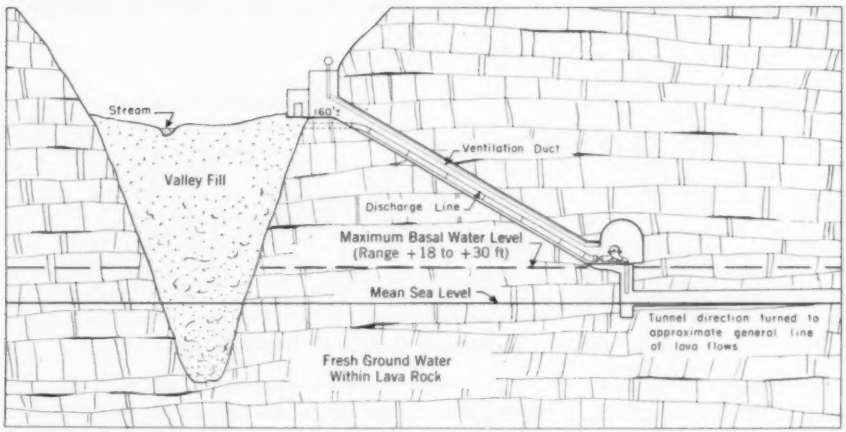

Fig. 5. Typical Underground Pumping Station

Shown in the cross-section diagram are the 30-deg inclined shaft, the pump room, and the sump and development tunnel near sea level.

with water. Tunnels through the dikes tap the water-filled compartments. The initial flow is usually four or five times the ultimate dependable flow.

The development of perched water for Honolulu began in 1920 when a tunnel was driven in Palolo Valley at an elevation of 987 ft. The success of this initial venture resulted in the installation of similar tunnels several years later in the other valleys fringing the city. Honolulu now has a total of seven sources of high-level water producing 3–4 mgd. The economic advantages of developing high-level water become obvious when it is realized that, since this water is supplied by gravity to residents in the upper-service zones, the necessity of pumping artesian water to excessive elevations is eliminated. Several of the large residential areas on the heights back of the city have elevations up to 1,000 ft, to which some water must still be boosted. Two of the booster stations—Kuliouou and Makiki—are shown in Fig. 6 and 7.

The discovery of artesian water and the subsequent installation of artesian pumping stations did not immediately supplant the use of surface water in Honolulu. As a matter of fact, it was not until 1923 that the use of surface water was abandoned. This move was made possible because of the new availability of artesian water and high cost of treating surface supplies. The four open reservoirs which were built about 60 years ago in Nuuanu Valley back of Honolulu are still in evidence. These reservoirs, with a total capacity of almost 700 mil gal, are now being used for flood control purposes.

Several aerators have been built in the Nuuanu Valley, where aeration of the high-level mountain water is necessary to reduce the carbon dioxide content.

During 1956 a small, experimental filter plant was built in Nuuanu Valley to recover water from a mountain stream. The filter was designed to operate without coagulation and at rates intermediate to those of rapid and slow sand filters. Hawaiian beach sand is being used as the filtering medium at the present time. With a design capacity of 1 mgd the results to date have been excellent. This modest project represents the first attempt by the Honolulu Board of Water Supply to utilize surface water.

Water Quality

Honolulu's water sanitation program is governed by standards of the USPHS, since interstate carriers are serviced by the city's system. In all the years since the inception of the system the record with the USPHS has been untarnished. Bacteriological certification has been continuously satisfactory, the coliform indexes invariably being zero or just a very small fraction of the allowables under public health standards.

The excellence of the Honolulu water supply is all the more remarkable when one considers that practically none of the water furnished is regularly chlorinated. The natural purity of the ground water supplies is attributable to an amazingly efficient filtering action of the soil and rock as rain water percolates slowly down to the water table. In order to meet possible emergencies, however, fully automatic chlorinators are installed in all of the primary pumping stations ready for immediate operation.

More as a precautionary rather than a remedial measure, all of Honolulu's high-level supplies are regularly chlorinated to maintain a 0.1-ppm residual at a minimum contact period of 30 min.

This practice is advisable because the shallow ground cover over these sources does not afford the degree of protection which is characteristic of the deep ground water supplies. Even in its raw state, the high-level supplies are usually of very good quality. This has been borne out by periodic bacteriological analysis and extremely low observed chlorine demands.

tem a rigid disinfection procedure is observed at all times when new or repaired sections of the system are put into service. Another phase of the preventive sanitation program which has gained greater importance of late is backflow protection. Although the need for backflow prevention is a continuing one, the board's sanitary engineers have accomplished a great deal

Fig. 6. Kuliouou Booster Pumping Station

The fact that almost none of Honolulu's water is regularly chlorinated makes it imperative that an extremely stringent program of preventive sanitation be maintained. Regular sanitary surveys are made of all intake areas, public entry into which is carefully restricted. Only those on official business and properly examined by the territorial Board of Health may enter the watershed. In order to prevent contamination in the distribution system a rigid disinfection procedure is observed at all times when new or repaired sections of the system are put into service. Another phase of the preventive sanitation program which has gained greater importance of late is backflow protection. Although the need for backflow prevention is a continuing one, the board's sanitary engineers have accomplished a great deal in eliminating undesirable conditions throughout the city. A few months ago the installation of backflow preventers along the entire Honolulu waterfront was completed.

Research and Investigation

An absolute necessity in helping to keep the water supply safe and palatable is the maintenance of well staffed chemical, bacteriological, and sanitary engineering laboratories. In addition

to research, the laboratories of the Honolulu water department conduct a daily check on the bacteriological quality of the entire water supply of the city. In keeping pace with world developments, up-to-date equipment for the detection of radioactivity is maintained and operated by the chemical laboratory.

Increasing demands on the underground supply have brought about complete deterioration or gradual failure of a large number of privately owned wells. In fact, some geologists and engineers are of the opinion that the salting up of other wells in Honolulu may be expected because they believe that the bottom portion of the

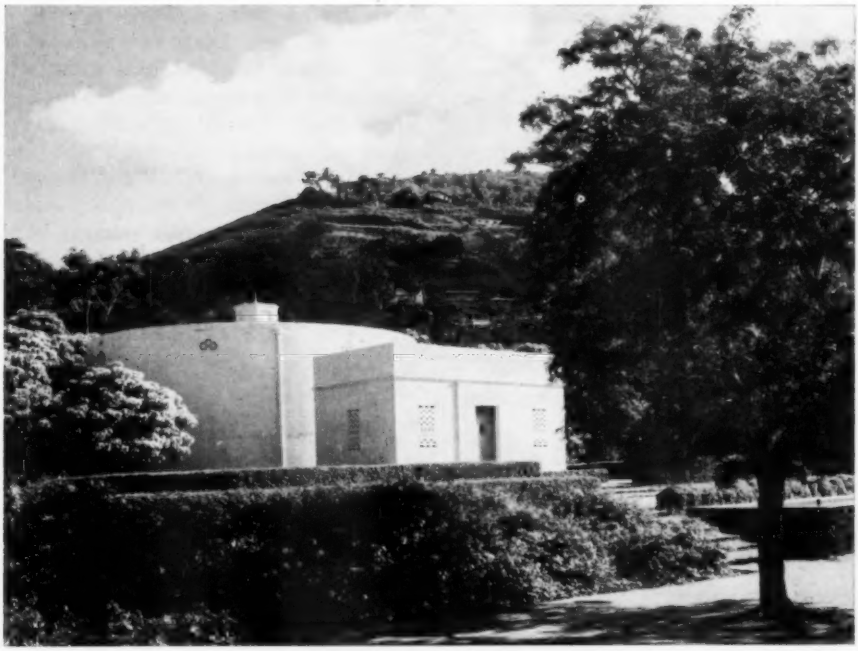

Fig. 7. Makiki Booster Pumping Station

The most important aspect of the department's research activities is centered around a vigorous and flexible program of water quality control compatible with operating needs and public health requirements. Needless to say, the technological demands for such a study require the constant and coordinated efforts of a number of specialists—the engineer, geologist, hydrologist, chemist, and microbiologist.

Ghyben-Herzberg lens is lagging during its attempt to attain equilibrium with a shrinking upper lens. For many years the department's technical personnel have been compiling and correlating data obtained from strategically located sampling wells in an effort to find out the interrelationship between head, chlorides, pumpage, and aquifer drawdown. Although the studies have been complicated by the

heterogeneity of the Hawaiian aquifer, it is felt that, at present, sea water intrusion in Honolulu is reasonably under control. Of course, research in this respect must be continuing because of the dynamic and intricate relationship of the natural phenomena involved.

The problem of ground water pollution has received considerable attention of late. The matter has become increasingly serious because the rapid development of the entire island has broadened the threat of surface contamination to underground sources. In cooperation with the USPHS and the territorial board of health, the Honolulu Board of Water Supply recently started a comprehensive research program in connection with the Federal Water Pollution Control Act. Generally speaking, five separate projects will be in progress within the next several years which will attempt to determine the extent and nature of underground and surface water pollution due to various causes. Of particular interest will be the use of bacterial, chemical, and radioactive tracers in field studies. It is hoped that valuable and interesting results will be obtained which will reflect the unusual nature of local geology and hydrology.

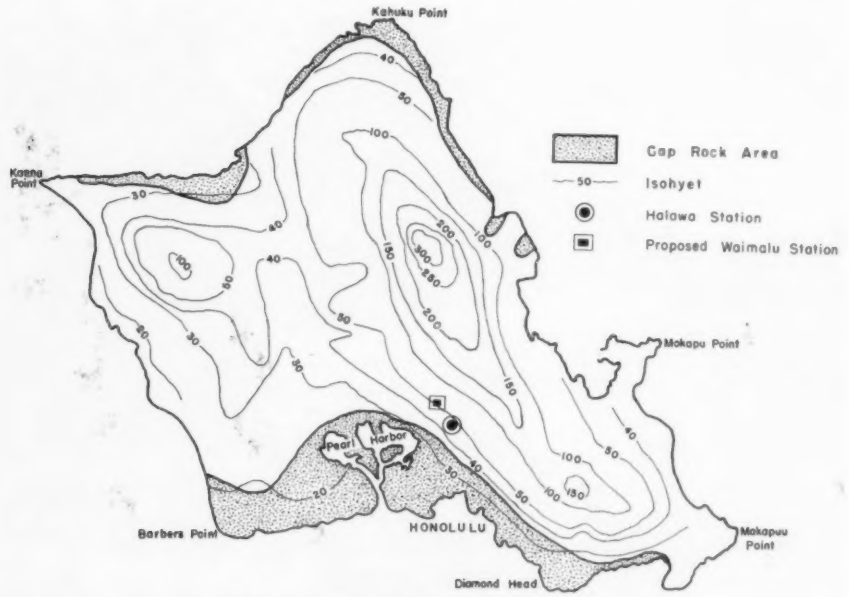

Fig. 8. Map of Oahu Island, Hawaii

Shaded portions indicate the cap rock area. Isohyet lines connect areas of equal rainfall, expressed in terms of inches per year.

Long-Range Considerations

The principal objective in Honolulu's water resources program is to project its planning at least 25 years into the future. The soundness of such a policy was strikingly exemplified during World War II and in the post-

war years when abnormal demands for water were met without serious threat to existing reserves. In preparation for the needs of a Honolulu with its peak development still ahead, the Board of Water Supply is currently working on plans with the dual purpose of developing additional supplies and conserving resources that are presently going to waste.

It was sometime prior to 1940 when Honolulu was faced with the realization that there were no further prospects of large-scale water developments within the city limits. Fortunately, territorial laws permit the city to go beyond its boundaries to develop needed supplies. Consequently, a new underground station was built in 1944 a few miles outside of the northwesterly limits of the city. Located far up in Halawa Valley, this station is at present the most important source of water for Honolulu. With an anticipated 40 per cent increase in population within the next two decades, plans are now under way for the construction of still another underground station in Waimalu Valley, some distance west of the Halawa station. When completed the Waimalu station will be the most ambitious project ever undertaken by the Honolulu Board of Water Supply, the design capacity being 20–30 mgd. The relative locations of the existing Halawa station and the proposed Waimalu station are shown in Fig. 8. Also indicated on the map is the proximity of the stations to the regions of maximum rainfall on the island.

Although its potential yield is somewhat limited, the development of high-level water in Honolulu is nevertheless most desirable because of obvious economic advantages. Within the next few years tapping of high-level sources in the Manoa and Kalihi valleys, with an expected combined yield of 1.5–2 mgd, is being planned. These supplies will serve, by gravity, areas that are now being furnished with pumped ground water. Although of relatively good quality, preliminary analyses of the Manoa and Kalihi sources show that nominal chlorination and aeration to remove carbon dioxide may be necessary.

It may be questioned why surface water is not more widely utilized in Honolulu. One reason is that there are only a few perennial streams in the city, the combined mean daily flow which is only about 10 mgd. Another reason is that, although maximum flows are many times greater than the mean daily flow, the impounding of water in the valleys is not feasible because of the high permeability of the valley sides. As the need of water for Honolulu becomes more urgent, however, particularly at the higher elevations, increasing attention is being directed toward fuller use and conservation of surface supplies. As mentioned earlier, filtration and direct utilization of surface water has already started in Honolulu. Furthermore, recharging of the aquifer with surface water, a practice which is gaining popularity throughout the United States mainland, may be attempted within the next year or two.

Although much more work needs to be done before the demineralization of brackish and sea water is to be perfected, staff engineers and chemists in Honolulu are nevertheless following all developments with great interest, because there are several areas within the territory where demineralized water will undoubtedly be used within a few years.

Review of the Jar Test

A. P. Black, Arthur M. Buswell, Fred A. Eidsness, and A. L. Black

A paper presented on May 14, 1957, at the Annual Conference, Atlantic City, N.J., by A. P. Black, Research Prof.; Arthur M. Buswell, Research Prof.; Fred A. Eidsness, Assoc. Research Prof.; and A. L. Black, Research Asst.; all of the Dept. of Chemistry, Univ. of Florida, Gainesville, Fla.

A PRELIMINARY survey of the general problem of coagulation as a step in the purification of potable waters has involved an extensive literature on the chemistry of the reactions of the conventional coagulants, aluminum sulfate and the iron sulfates, which result in floc formation. Several different colloidal theories have been advanced to explain the complex mechanisms which appear to be involved. Although much theoretical work remains to be done, it appears that the industry is faced with an unusual situation where in many cases theory is ahead of practice—that in water treatment it has failed in many instances to make practical application of the results of laboratory research. The reason for this state of affairs is not difficult to find. By its very size a water treatment plant does not lend itself to rapid and experimental changes in methods of operation, nor is it possible, because of the continuous nature of the treatment process and the necessity for turning out at all times a safe and usable product, to risk those unsuccessful results which are so universally encountered in research. This situation has been met in part by the development of the jar test, and it is for the purpose of advancing knowledge and use of that test that this review has been prepared.

For the purpose of this discussion, the jar test for determining coagulant dosage in water treatment may be defined as a test in which comparisons are made between the results of two or more samples and making use of a multiple stirring device by which the time, type, and velocity of stirring may be varied.

At the outset, it should be made clear that the idea of the jar test is well conceived and ingeniously applied, but, as this review will show, relatively little has been done to standardize either the equipment or the method of operation. Because of the paucity of the printed reports on the earlier work on the subject, it is believed that there must be a great deal of unpublished data in the files of plant operators and chemistry laboratories. A great deal of the material presented in this review has been obtained through personal correspondence between the authors and many of the older workers in the field. It is hoped that this review will serve to draw out that material either through the pages of this JOURNAL or through direct correspondence with the authors.

Results of Questionnaire

In order to supplement this correspondence and the material obtained from a careful review of the literature,

the authors prepared and distributed a questionnaire so designed as to bring out the essential details of the jar test as conducted by different individuals and laboratories. This questionnaire was sent to each of the sixteen leading manufacturers of water works equipment or supplies, to each of the fifteen consulting engineers offering laboratory services, to nine water works laboratories in the larger plants of the country, and to four government or university laboratories. To date 32 completed questionnaires have been received, and many have been accompanied by extended memoranda or monographs describing the use of the jar test in individual situations.

Of the 32 replies which have been received, fourteen came from manufacturers, six from consulting engineers, eight from water works laboratories, and four from government or university laboratories. About the only conclusion which can be drawn with confidence from the results obtained is that there is little or no uniformity in methods used for conducting the jar test—that there are about as many individual variations in procedures as there are individuals carrying out the test. There is, however, a certain degree of uniformity in equipment use. Seventeen of the laboratories replying use the only multiple stirrer now offered on the American market for conducting the jar test. Six laboratories use a multiple stirrer first designed and offered for sale in 1930 or 1931, but which has been withdrawn from the market. Nine laboratories use stirrers especially designed, but descriptions or photographs indicate that they do not differ greatly from the two types just mentioned.

Early Experiments

Before reviewing the development of the jar test it should first be noted that much important information and many contributions to basic theory have been forthcoming without the use of the jar test. Perhaps the most outstanding example is the work of George W. Fuller (*1*) in his studies of the method of treatment of the Ohio River water made at Louisville, Ky., in 1898. The device which he used in his studies was essentially a pilot plant consisting of a settling basin 20 in. in diameter and 24 ft deep. It was provided with a series of petcocks by which samples of water could be drawn during treatment at stated distances from the bottom. Sedimentation studies were made with and without the addition of a coagulant, aluminum sulfate. In discussing the factors influencing coagulation, Fuller made no mention of agitation or mixing before or during the addition of the coagulant.

In the same year James M. Caird (*2*) conducted tests on the coagulation of the waters of Elmira, N.Y., which closely approached present jar test technique. In his own words:

> It was our practice to have a measured quantity of water in a glass bowl, about 6 in. deep and 12 in. in diameter, and to add a standard solution of sulfate of alumina from a burette with constant hand stirring until a point was reached which we considered was the proper amount of alumina to give us the desired coagulation.

The Illinois State Water Survey group working under Bartow in the period 1907–17 appear to have made no use of jar tests. In Smith's (*3*) words, "I did not use a machine. We set up jars and added the coagulant, then mixed for a given number of shakes, and allowed to settle for a given time and made observations."

Wellington Donaldson (*4*) who, as chemist for the American Water Works and Guarantee Company, was very active in the water treatment field

during the period 1906–20, recalls the occasional use of bottles or jars to determine the proper chemical dosage, but states that "no use was made of mechanical stirrers, whether single or gang."

Hoover was using multiple jar tests but without continuous stirring at Columbus in the early 1920's and perhaps before. In the words of Laux (*5*), then his assistant:

> I worked in the laboratory at the Columbus treatment plant beginning in April of 1921 and spent, as I remember, 4 years working for Mr. Hoover. One of my first jobs was to carry buckets of water from the river and measure it out in gallon samples into large wide-mouth jars. Mr. Hoover then added varied dosages of alum solution and lime and soda-ash. I started at one end of the table and shook each jar for a minute until I got to the end of the line and then I started over for a second trip. This was kept up for 30 min (without a coffee break). This had been the practice previous to 1921 to determine the amount of alum dosage needed and frequently to check on the dosages of lime and soda-ash for water treatment. I cannot find a record, but in 1923 or 1924 the Okey Manufacturing Company of Columbus built a stirring machine. It was large and cumbersome but is still in use and, I believe, just about as effective as the smaller types of machines that are now being manufactured. The distinctive feature of this piece of equipment was the method of obtaining variable speed. The shaft carrying the paddle was rigid and could not be detached. On top of each shaft was a wooden leather-covered disc about 12 in. in diameter. The motor drove a horizontal shaft, on which were mounted small drive pulleys, which operated the shaft by rotating the large disc. Speed could be varied by moving this smaller pulley either toward the center or the circumference of the disc.

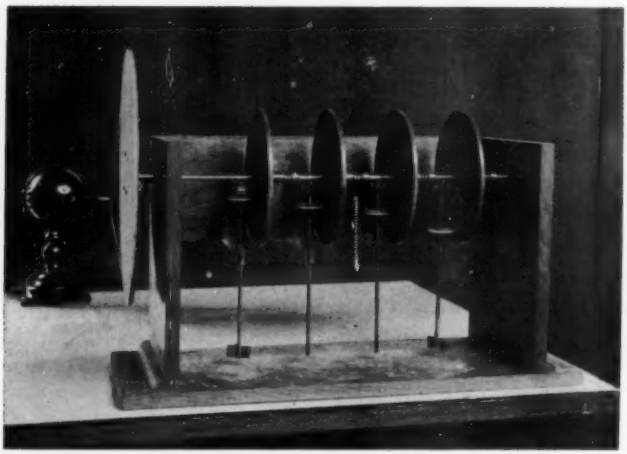

Fig. 1. Langelier's Stirring Machine

A 1921 model of a machine developed by W. F. Langelier in 1918 and believed to be the first of its kind. The original machine did not have the variable speed friction drive shown above.

Inspection of Fig. 1 and 2, in the light of the description of the machine described, indicates that its design was unquestionably influenced by the machines constructed and used by Langelier and Baylis.

Theriault, Clark, and Miller (*6–10*) in their five classical papers published during the period 1923–25 did not use the jar test and yet were able to make important contributions to the theory of coagulation. Miller was one of the first to bring to the attention of the water works chemist the role of the trivalent alum and ferric ions in neutralizing and precipitating the negatively charged colloids of color or turbidity and to conclude that the absorptive property of the gelatinous floc plays, as a rule, a relatively unimportant part in the process. In their studies these workers showed: [1] that there must be present a certain minimum quantity of alum or ferric cation; [2] that there should be present an anion of strong coagulating power; and [3] that the pH must be carefully adjusted.

Most of their experiments were conducted in beakers or graduated cylinders and stirring, if any, was by hand. They did realize, however, the importance of the physical factors in coagulation since they state: "Now it is most interesting to note that the time of flocculation can be varied by forming the mix in vessels of different size." For this purpose they used a large shallow tank supplying buffer solution through a 1-in. pipe to an inclined trough at the upper end of which a small constant stream of alum solution was added. The lower end of the inclined trough was provided with a hydraulic jump. When the mixture being coagulated was collected in vessels of varying size it was noted that invariably the time for first floc was least in the largest vessel. They obtained the same results by hand mixing and pouring the water being treated into vessels of different sizes.

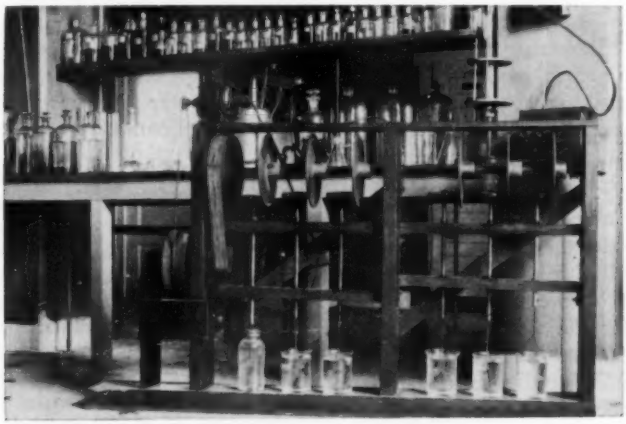

Fig. 2. Baylis's Stirring Machine

J. R. Baylis used this jar test machine at Baltimore in 1920. This is believed to be the second device of this type.

They finally concluded—and, as is now known, correctly—that this so-called "volume effect" was nothing more than the effect of the volume-surface ratio upon circulation. They conducted a series of experiments in which "slow rotary motion was imparted to the samples" and concluded that "the total amount of floc seemed not to be affected and the optimum pH remained the same, but the time values were altered from those shown in preceding tables."

First Jar Test

A careful study of the literature and correspondence with older workers in the field indicate that the first jar test, as the authors have defined the term, was probably run in 1918 at the University of California by W. F. Langelier (*11*) under the direction of Charles Gilman Hyde during the course of investigations of the proper method of treatment for the water supply of the city of Sacramento, Calif. George E. Willcomb (*12*) credits Langelier with the first large scale application of mechanical agitation at Sacramento in 1921 and characterizes it as a direct result of laboratory studies. Discussing the theory of coagulation then current, Langelier states (*11*):

> Most engineers favor the idea that only the slightest agitation possible is desirable after an initial reasonably thorough mixing of the alum with the water. This theory is not in accord with any of the experimental data which we have obtained. Our results checked many times under varying conditions, indicate that prolonged agitation is not objectionable but is highly desirable in increasing the efficiency of the process.

Then follows what is believed to be the first description of a jar test to be found in the literature.

The apparatus used to determine the ideal conditions of agitation consists of a wooden frame on which are mounted four rotating paddles or propellers, each geared to a horizontal shaft driven by a small electric motor. The water is held in cylindrical glass jars 5 in. in diameter and 10 in. deep. A later modification of the device is designed with friction disks which permit the operation of each paddle at a speed independent of the others. The same effect of variable agitation can be produced in the original apparatus by using paddles of different sizes. These simple devices have proved extremely useful in studying coagulation phenomena. Similar apparatus could with profit be included in the laboratory equipment of all water purification plants using coagulation.

With this device the Sacramento River water could be effectively coagulated with dosages of alum varying between 0.5 and 0.8 grains per gallon for a considerable range in turbidity and alkalinity. Without agitation, other than that required initially to thoroughly mixed the coagulant solution with water, these same dosages failed to coagulate the water at all. Observations showed that an increase in turbidity from 20 to 200 ppm had practically no effect on the speed of coagulation, and that but slightly larger doses of coagulant were necessary with the more turbid water to secure the same final clarification. An increase in alkalinity, other conditions remaining constant, necessitated either a more prolonged period of agitation or an increased dosage of alum. The velocity of the water during agitation in the different trials was made to vary. The actual velocities were estimated to range from 0.2 to 1 fps. Later studies showed that velocities up to 2 fps, or even higher, could be prolonged for a considerable period without breaking the floc or reducing the efficiency of the process. In general, the highest velocities produced the most rapid flocculation. The period of agitation in these experiments varied between 10 and 20 min.

In his early work, Langelier clearly sensed the importance of the hydrogen-ion concentration of the water for proper coagulation. Quoting again from his paper (*11*):

One of the most important observations that has been made in connection with these studies is the part played by the 'reaction' of the water or what chemists term 'hydrogen-ion concentration.' Aluminum hydroxide is least soluble, and consequently most quickly and completely precipitated, in a medium the reaction of which is close to true neutrality. The reaction of raw water is usually alkaline. This, however, depends not merely upon the alkalinity as determined by titration with an acid, but rather upon the ratio of this potential alkalinity to the amount of free carbon dioxide present. With waters low in CO_2 the dosage of alum necessary to produce approximate neutrality is the amount that will reduce the alkalinity one-fifth. Therefore, if the alkalinity of the water is low, the alum necessary to raise the hydrogen-ion concentration to approximate true neutrality, and thereby induce rapid precipitation and coagulation, is correspondingly low. It is apparent, then, that more often an acid, rather than a base, should be employed as a means of inducing rapid coagulation with alum. It would appear, moreover, from an extensive series of observations that we must revise our ideas in regard to the desirability of a 'basic' alum.

Langelier's stirring machine is shown in Fig. 1.

Developments by Others

John R. Baylis (*13*), then at Baltimore, began to employ the jar test in 1920. In his own words:

In 1920 I began using the jar test extensively in work of coagulation. The first machine was constructed in which there was a shaft with beveled gears for operating the stirrers. I do not recall the number of stirrers used, although I believe there were three. We used this machine considerably, but it had the disadvantage that the speed of the stirrers could not be varied easily. Either in 1921 or 1922 I had another machine made for six samples of water. In looking through my photographs, I find a negative showing the machine, which was dated January 1, 1924. The machine had been used 2 or 3 years before the photograph was made.

Baylis's stirring machine is shown in Fig. 2.

In 1928 Bartow and Peterson (*14*) published their important paper on the effect of salts on the rate of coagulation and optimum precipitation of alum floc. In this paper they reemphasized the importance of pH on floc formation; again called attention to the fact that alum floc is often not $Al(OH)_3$, but a more complex substance, and showed that ions present in solution exert a profound effect on floc formation. They stated that each water has its own individual optimum zone of floc formation. In this work a shaking machine was used for mechanical agitation of samples.

John D. Fleming (*15*) in 1930 called attention to the fact that a clear distinction should be made between mixing and conditioning. In his own words:

Mixing is a term which should be applied only to the process by which homogenity of the water and applied chemicals is established. Conditioning is the treatment by which flocculation of this homogeneous mixture is promoted and consists of the general agitation of the mass for 10–40 min, in such a manner as will give the suspended matter in the water a motion relative to the general motion of the water.

Willcomb (*12*) reemphasizes the same thought in the following words:

Mixing is the rapid diffusion of the chemical coagulating solutions through-

out the body of water being treated. Since floc formation is almost instantaneous, mixing may well include the idea of floc formation. But the coalescing of the floc particles into masses is a distinct operation influencing time and physical change of the colloidal flocs formed in the mixing action into new and heavier formations. This process is best described by the word 'conditioning' and it is, therefore, suggested that the word 'conditioning' be substituted for mixing in describing purification plant layouts.

In his work Willcomb used a homemade jar tester involving the use of flat metal discs attached to vertical rods and given an up and down motion by a horizontal rocker arm. He indicates his preference for such a device, rather than one employing rotary paddles, and calls attention to the fact that a worn thrust bearing on a vertical rotating shaft carrying a paddle has produced enough eccentricity to give better floc formation with a 1.5-grain dose of alum than a 2.0-grain dose in an ascending series.

In 1933, Nolte and Kramer (*16*) emphasized the importance of proper mixing. In their words:

> The conflict among observations made by various experimenters is not due altogether to the character of the water or to the chemical dosages, but may be partly attributed to the methods used for measuring and obtaining these velocities in laboratory experiments. The procedure is not standardized for some measure the velocity at two-thirds the distance from the center of the paddle, while others calculate the velocity at the end of the paddle. The size of the containers with reference to the size of the paddle also makes considerable difference in results and this phase has received no attention. . . . Until a standard method for laboratory and plant practice has been adopted, very close agreement cannot be expected.

In their studies of turbidity removal with aluminum sulfate. Nolte and Kramer used velocities varying from 0.15 to 3.0 fps, and concluded that there is a certain optimum dosage of aluminum sulfate for every water and that a deficiency in this dosage will give poor results regardless of agitation.

Black, Rice, and Bartow (*17*), studying floc formation by aluminum sulfate, confirmed the results of Bartow and Peterson (*14*) regarding the effect of the chloride, sulfate, and other ions on floc formation, and presented a series of tables emphasizing the importance of continuous stirring. The results of pilot plant tests are shown to confirm laboratory observations.

In their studies they employed a six-unit machine equipped with 3 × 15-cm glass blades attached to 1 × 25-cm glass rods. These, in turn, were attached to vertical steel shafts by heavy-wall rubber tubing so that any stirrer might be disconnected and a jar removed during a run. They used 3.5-liter battery jars to contain 2-liter samples. Identical conditions of illumination and the formation of Tyndall cones were provided. The recommended stirring rate was 52 rpm.

Bartow, Black, and Sansbury (*18*), in their studies employing ferric coagulants, presented conclusive evidence that flocs formed in the acid range carry positive charges, that those above pH 8.5–9.0 are usually negative, and that within the pH range 7.0–8.5 there is a zone of slow or no floc formation, within which the floc particles undergo a change in sign. On this basis they explained the difficulties encountered in removing organic color from water at high pH values, and they showed that whereas negatively charged ions such as sulfate are effective in decreasing floc times in the acid range, bivalent

positively charged ions are likewise effective in decreasing floc times in the alkaline range.

With the thought in mind that from Schulz's rule an ion with a valence of four should be extremely effective in coagulation, Upton and Buswell (*19*) in 1937 investigated titanium sulfate and mixtures of ferric and titanium sulfates as coagulants. One-gallon battery jars were used, and samples were stirred mechanically with wooden paddles which revolved about one-third of the way down in the liquid at speeds of 45–60 rpm. Stirring periods as long as 3 hr were used in some of the tests. Hydrous titanium oxide floc was found to be more bulky and opaque than alum floc, but it settled somewhat more slowly at ordinary temperatures. However, titanium sulfate was found to be superior to alum at temperatures near the freezing point of water.

Also in 1937, Olin and Peterson (*20*) studied the use of bentonite as a coagulant. Bentonite flocs were found to be more bulky and to occupy more volume on settling than flocs formed with filter alum. They found that there must be present a minimum concentration of 100-ppm total dissolved solids for bentonite to swell and flocculate. They further noted that due to exchange capacity the use of bentonite provides some softening action. The jar test does not appear to have been used in this work.

Baylis (*21*) in his important studies of activated silica as a coagulant aid employed 1-liter beakers and a stirring velocity of 1 fps. Flocs were described as "just visible," "small particles," "fairly good," "good," "excellent," and "immense." Observations were made over stirring periods up to 30 min. and it is believed that this is the first instance in which the term "immense" appears in the water works literature.

Later Developments

Samuel L. Tolman (*22*) in his 1942 article on flocculation practices at Indianapolis described a laboratory mixer consisting of two $\frac{1}{4} \times 3$-in. vertical arms attached to two horizontal arms 1 in. from the vertical shaft. Variable speed was provided, 1-liter samples used, and 20-min stirring periods followed by 30-min detention periods were found to duplicate plant performance.

J. B. Nickel (*23*), in his comprehensive discussion of jar test techniques, states that uniform results cannot be expected with samples of less than 1 liter, and that little is to be gained by employing larger samples. He states that total mixing time may vary from 10 to 45 min, using 2-in. or 3-in. blades, and suggests 100 rpm for rapid mix and 25–40 rpm for slow mix.

R. W. Ockershausen (*24*), in discussing factors in the jar test, prefers 2-qt samples, although he states that 1-qt samples are adequate. He emphasizes that the stirring machine should be started before the coagulant is added. The initial rapid mix, which may be of one or more minutes, is to be followed by a slow mix period of from 10 to 30 min.

Langelier and Ludwig (*25*) in their important study of the flocculation of turbid waters employed a stirring device having 8 jars. They used 200-ml samples and a stirring velocity of 72 rpm. Following 10-min rapid mix, samples were settled and tested.

Cross, Gallaher, Filicky, and Hassler (*26*) in their studies of the removal of synthetic detergent by coagulation used 1-liter samples of Lake Michigan water and a 15-min mixing period at a speed

of 44 rpm. Samples were allowed to settle for 30 min, after which turbidities were determined.

C. R. Henry (*27*), in his studies of activated silica as a coagulant for lime softening, used 2-liter samples, a 5-min rapid mixing period at 160 rpm, followed by a 15-min slow mixing period at 40 rpm.

Smith, Cohen, and Walton (*28*), in their study of the effect of synthetic detergents on coagulation, employed a six-place laboratory stirrer, 1-gal wide-mouth, square sided jars, and 2-liter samples. Following the addition of coagulant, samples were stirred for 30 min at 42 rpm, which provided a paddle tip velocity of 43 fpm. Time of first floc formation was noted and observations of floc quality made during the coagulation period. Coagulated samples were allowed to settle for 60 min before testing.

Straub, Morton, and Placak (*29*), in their studies on the removal of radioactive contaminants from water by coagulation, employed a 3-min rapid mixing period, followed by a 27-min slow mix and a settling period of 30 min. Size of samples and mixing velocities are not given.

Rolf Eliassen (*30*) and his group in their basic studies of coagulation used a six-unit stirring machine and a mixing period of 20 min at 40 rpm.

George D. Norcom (*31*) recommends a multiunit machine and states that either 1-qt or 1-gal jars may be used, although the latter are preferable. A 3-min rapid mixing period is to be followed by a 15-min slow mixing period and 3 hr of settling. Mixing velocities are not stated.

Charles R. Cox (*32*), in discussing the jar test, recommends a multiple stirrer unit, 1-liter samples, and a mixing period which may vary from 10 to 30 min at velocities of 30–100 rpm. He states that the required degree of agitation and the mixing period are inversely related—that is, a higher degree of agitation is required for a shorter mixing period. Plant conditions should be duplicated as far as possible.

R. F. Packham (*33*) reports that the situation in Great Britain is similar to that in this country in that, in his own words: "None of these machines are alike." The jar test machine used by his group of the British Waterworks Association is provided with six stirrers. Each stirrer is made up of four vertical flat blades, $\frac{3}{4}$ in. wide and the radius of the stirrer path is 2 in. In conducting the jar test, 1,000-ml tall round jars are used. A 2-min period of rapid mix at 200 rpm is followed by a 15-min period of slow mix at 20 rpm. After 10 min. settling, 200-mm samples are carefully decanted for analysis.

Question of Standardization

As has been stated previously, results of the 32 questionnaires which were returned indicate, as have the numerous references cited, that there is no uniformity among different laboratories or workers in carrying out the jar test. It does appear, however, that the majority of workers employ a fairly short period of rapid mixing followed by a longer period of slower mixing. Furthermore, there is a definite tendency, specifically stated by many workers, to attempt to duplicate as far as possible in the jar test conditions found in individual plants.

Since the jar test carried out under widely differing conditions has unquestionably been the most valuable single tool in the hands of the water chemist in applying the process of coagulation to water, it may be asked if the test can

be or should be standardized. Many feel that it should, since by so doing comparison of results and exchange of information between different laboratories would be facilitated.

Thomas R. Camp (*34*), in discussing this question, states:

> Other questions which arise in considering the advisability of standardization are the objectives of the jar test. If the jar test is for the purpose of determining the optimum pH or the optimum dose of coagulant in routine plant operation, the time required for first appearance of floc in a Tyndall cone may be used as a parameter. In this case, the settleability of the floc does not become a complicating factor. If, on the other hand, the purpose of the jar test is to determine the violence of the agitation and the required time of coagulation and the design factor for sedimentation, flocculation must be followed by sedimentation in the same container or jar. Many complicating factors arise in this connection relative to standardization of the jar test. . . . It should be emphasized that it is not possible to develop a laboratory mixing device which is a true hydraulic model of a prototype mixing chamber for the reason that the floc itself is full scale in both laboratory device and the prototype. If, however, the laboratory stirring device is geometrically similar to a prototype mixing chamber, the liquid flow pattern in the mixing chamber may be reproduced in the laboratory stirring device in conformity with model laws.

In view of the fact that there is no single basic theory of coagulation to which all workers subscribe, it does not seem possible or feasible to attempt at this time to standardize the jar test. This must await a clarification of certain fundamental questions which still remain to be answered. In the meantime, it may be stated that of all the factors influencing the carrying out of the jar test the following would appear to be those which are most important and upon which agreement should be reached as soon as possible:

1. The size of the sample
2. The size and shape of the container
3. Peripheral speed and time of rapid mix
4. Peripheral speed and time of slow mix
5. Criteria for establishing optimum dosage.

It is believed that if these five factors can be standardized, substantial agreement would be realized between work carried out by different individuals in different laboratories. Meanwhile, one cannot escape the conclusion that even though methods for conducting the jar test vary widely, it still remains by all odds the most valuable tool in the hands of the water chemist to determine the best and most economical dosage for a given water.

Acknowledgments

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Improved Jar Test Procedure

Jesse M. Cohen

A contribution to the Journal by Jesse M. Cohen, Chemist, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THE jar test, in spite of its known shortcomings, has proved valuable in water plant operation, particularly in the hands of an experienced individual. When the jar test is required in coagulation research, however, need for an objective and quantitative measure of the results of the test soon becomes apparent. In conjunction with coagulation investigations undertaken at the Robert A. Taft Sanitary Engineering Center, a method was developed which has largely filled this need.

Settling rate of a floc was determined by Camp, Root, and Bhoota (*1*) by analyzing for iron in a series of samples withdrawn at measured time intervals from six jars during the settling period. From these data, a curve was constructed by plotting percentage of iron remaining against settling time in minutes. Samples were siphoned out successively from each jar through copper sampling tubes from a depth of 2¼ in. above the bottom of the jars. The problem in this procedure was the difficulty in obtaining samples from six jars simultaneously. With rapidly settling floc, small differences in sampling times introduce errors which preclude comparison of the resulting curves.

Attempts to use determinations of iron to define the settling rate resulted in inconsistent results, which were ascribed to the uneven distribution of the floc due to its varying size. Further, an important effect of a coagulation was ignored, namely removal of turbidity. In the procedure described turbidity rather than coagulant ion, for example, residual aluminum or iron, was determined. This modification has additional advantages in that turbidity determinations are made rapidly, are subject to no ion interferences, and do not depend on the availability of a chemical analytical procedure. Lack of a suitable analytical method for small concentrations of aluminum ion precluded determination of settling rate of alum floc. Determination of turbidity, in addition to yielding data for settling rate, also defines the quality of a coagulation by indicating the amount of particulate matter, other than floc, remaining in suspension.

Laboratory Apparatus

Construction of settling curves for a series of six jar tests requires that samples be obtained from each of the jars within time intervals as short as 1 min. For the settling curves to be directly comparable, samples must either be obtained as nearly simultaneously as possible or sampling times must be known accurately. This requirement becomes strikingly apparent in tests where 95 per cent of the floc settles within 3 min.

To meet this requirement effectively, a sampling device was developed which permits simultaneous removal of small samples at a predetermined depth from six jars. Each set of samples can be obtained within 5 sec, and successive

sets of samples can be obtained within 30 sec. This rapid and simultaneous sampling from six jars is accomplished by the device shown in Fig. 1.

This apparatus is easily constructed from materials present in most laboratories and from certain items which are otherwise readily available. Basically, the device obtains samples from each of the six jars by applying controlled reduced pressure to small sample containers. Sample containers are individually connected to a vacuum manifold. Control of the vacuum to each bottle is afforded by small needle valves. These valves must be adjusted once and thereafter need no further attention, the rate of sampling being controlled by the control valve (Item 10 in Fig. 1).

Details of construction shown in Fig. 1 are:

1. Six-place mechanical stirrer
2. Six wide-mouth square jars, each 1 gal capacity

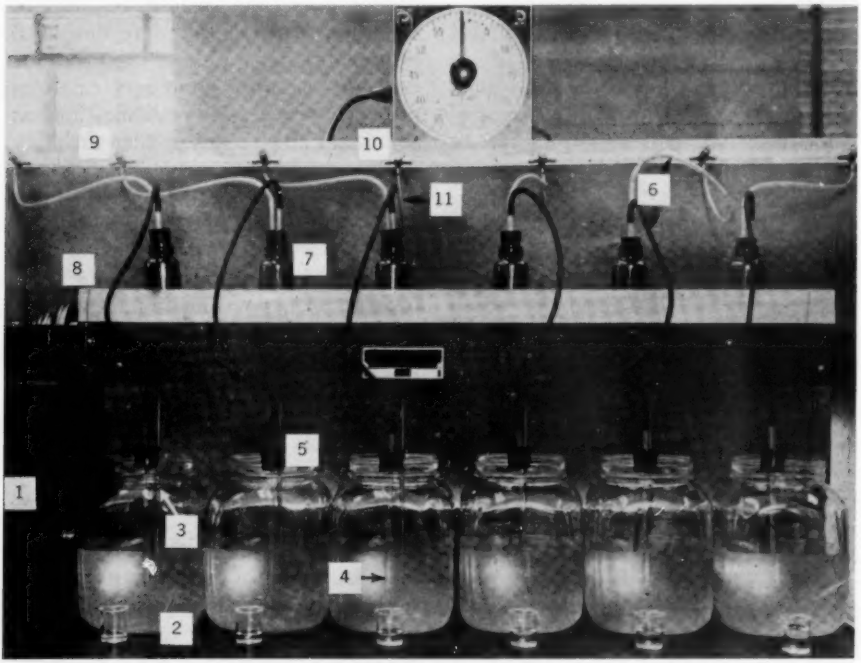

Fig. 1. New Jar Test Apparatus

This device permits simultaneous and rapid sampling from six jars. Numbers refer to details of construction explained in the text.

3. Stainless steel stirring paddle, $\frac{3}{4} \times 3\frac{1}{8}$ in.
4. Glass sampling tubes, 1.5-mm ID bore, positioned at midwater depth which corresponds to 2 in. below the water surface
5. One-hole No. 6 rubber stopper, slotted to fit over edge of jar to support sampling tube

6. Rubber or plastic connecting tubing, 4.0-mm ID

7. Sample bottles (60 ml), each fitted with a two-holed rubber stopper (Number of bottles depends on time interval desired, each time interval requiring six bottles.)

8. Wood support drilled to hold securely six sample bottles

9. Small brass regulating needle valves, which may be purchased from aquarium supply houses (Two two-outlet valves positioned at both ends and five three-outlet valves.)

10. Control valve, the only valve operated during sampling

11. Tubing connected to a vacuum source, which may be mechanical or a water aspirator.

In a typical operation, the apparatus is set up as illustrated in Fig. 1. Valves to each sample container are open to the proper adjustment, but the control valve is closed. Immediately following coagulation, the interval timer is set for the desired settling period. At the proper time the control valve is opened and samples from each of the six 1-gal jars will flow to the sample containers. These sample bottles are replaced with empty containers, and another set of samples may be obtained. The apparatus permits the obtaining of a set of samples once a minute.

Following collection of samples, determinations for turbidity are rapidly made by using a spectrophotometer or filter photometer previously calibrated against a standard turbidity suspension obtained by measurement with the Jackson candle turbidimeter. Turbidity values obtained with the spectrophotometer reflect the presence of both clay particles and fine floc. Turbidity measurements, dependent on decrease of light transmission, are inherently sensitive to particle size. Since the size of the particles in these measurements varied from colloidal clay to fine floc, some difficulty with turbidity measurement was anticipated at first. Experience with this type of turbidity measurement for construction of a settling curve, however, has proved that fears of difficulty were unwarranted. Determination of turbidities on samples obtained at 1-min intervals from a coagulation jar has invariably resulted in a smooth curve.

Various methods of plotting the results of turbidity measurements were investigated, the final choice being a plot on semilog paper of percentage turbidity remaining on the log scale against time in minutes on the arithmetic scale.

Typical Data

In the past 2 years several hundred settling rate curves have been obtained. Inspection of any individual set of curves allows an exact evaluation of the quality of coagulation obtained.

To determine the reproducibility of the settling curves, six identical coagulations were made using alum and a synthetic turbid water. An amount of 10 mg/l of alum was added to water containing 106 units of turbidity. Flocculation was continued for 30 min, following which samples for turbidity measurement were taken at 1, 2, 3, 5, and 30 min of settling. The resulting set of six replicate tests was analyzed statistically to determine the reproducibility of the method.

The data obtained from each of the six jars were used to plot six corresponding settling rate curves on semilogarithmic graph paper. Analysis of variance of these data showed that the settling rates were the same in each

of the six jars within the limits of the errors of measurement.

The curve shown in Fig. 2 was fitted by the least-squares method. This curve is the best linear predictor of those turbidities corresponding to settling times within 1–30 min range, and should be looked upon as an adequate approximation, within the limits of experimental error, to some exact functional relationship.

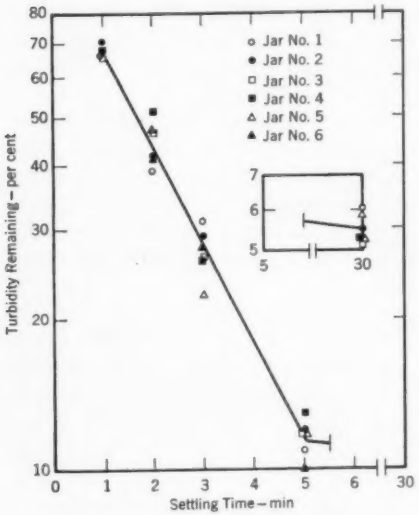

Fig. 2. Settling Rate for Six Identical Coagulations

The curve was obtained from results of six coagulations, each using 10 mg/l alum in water with 106 units of turbidity. The insert shows results at the end of 30-min settling time. Samples were taken at times indicated by symbols.

At zero minutes settling time, a boundary condition exists such that 100 per cent turbidity remains. The fitted line was not required to pass through this point, since no data exist which permit a test of the adequacy of the linear approximation when settling times shorter than 1 min are considered.

The standard error of turbidity measurements made on the samples drawn simultaneously from different jars was found to be 8.6 per cent. The error was the same for settling times ranging from 1–30 min, during which time the turbidity varied between 70 per cent and 5 per cent of the initial amount.

For this set of coagulations, the observations were plotted linearly on semilog paper during the first 5 min. The floc settled during these first 5 min at a rate such that 64 per cent of the turbidity present at the start of each minute was still present at the end of that minute. Between 5- and 30-min settling time, the average settling rate was much slower, the average residual turbidity after each minute of settling amounting to 97 per cent as compared to the 64 per cent for the first 5 min.

The jar test is frequently employed to determine the amount of coagulant required for good coagulation. The object is to produce the best possible floc which will properly clarify the water with the least amount of chemicals. In conventional practice the ability to tell whether or not the dosage is satisfactory is largely dependent on the extent of experience of the technician. With the method described, such experience is not necessary. In addition, a permanent record of coagulation results is acquired and may be filed for reference or for later study. Figure 3 shows the settling rate curves of a series of ferric sulfate coagulations. Information was desired on the amount of ferric sulfate coagulant required to produce the best coagulation in a water known to contain an interfering substance. A single series of jar tests sup-

plied the necessary information. The original turbidity of the water was 95 units. In this series of coagulations, residual turbidities greater than 5 units in the effluent after settling for 60 min were considered unsatisfactory. This criterion immediately eliminates the doses of ferric sulfate up to and including 30 mg/l. No coagulation was obtained with 24 mg/l. The 32-mg/l dose almost meets this requirement with a residual turbidity of 5.7 units, and represents the minimum amount of coagulant. An increment of just 2 mg/l of ferric sulfate, however, resulted in a final turbidity of three units and, in addition, produced a more rapidly settling floc. This dose, 34 mg/l, then, is clearly and unequivocally the optimum dose of ferric sulfate in this series of coagulations.

Besides providing information on the rate of settling of a floc and degree of clarification, additional information may be obtained on the quality of coagulation from the shape of the curves. Figure 4 shows several types of settling rate curves frequently obtained. Curve *A* indicates a coagulation which produced a uniformly fine floc so small that at the end of 1–2-min settling the supernatant had a turbidity higher than the starting water, due, in part, to the fine floc which resisted settling. Settling was slow, and the final turbidity excessive. This coagulation would not be satisfactory in a water treatment plant. Curve *B* represents

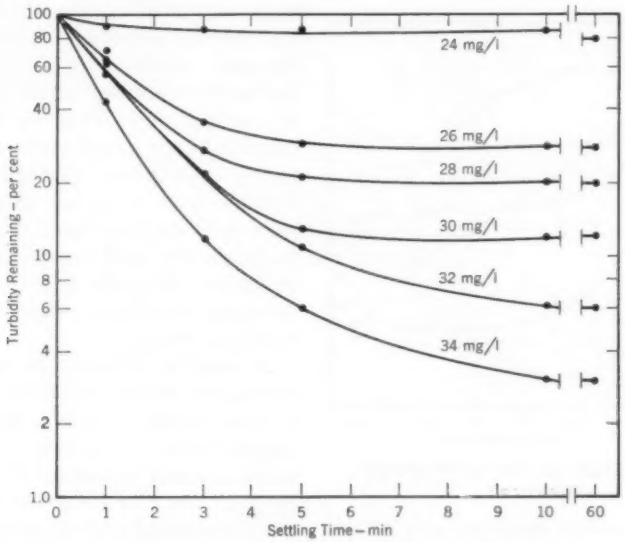

Fig. 3. Effects of Increasing Amounts of Coagulant

Ferric sulfate was added to six jars in amounts shown. Original turbidity of the water was 95 units. Dots indicate sampling points.

the most common type of settling rate obtained. During the first 5 min, the settling rate curve is practically a straight line on a semilog plot. Settling was rapid and clarification was satisfactory. The coagulation represented by curve *C* shows that a mixture of large rapid-settling floc and small slow-settling particles was obtained. Settling was rapid for the first 2 min but with little further clarification after

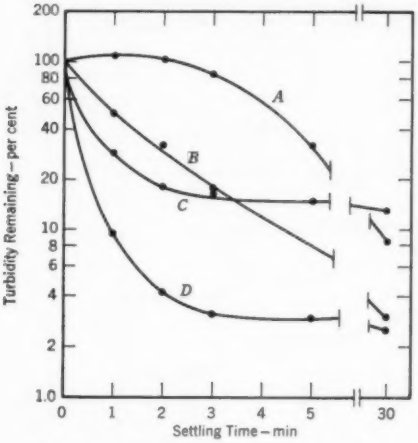

Fig. 4. Types of Curves Frequently Obtained

Shapes of curves indicate types of settling rates obtained with alum coagulation in water with original turbidity of 100 units. All curves are analyzed in the text, with Curve D *representing the best results. Dots indicate sampling points.*

that. High residual turbidity may also have resulted from incomplete clarification. Curve *D* represents the ultimate in coagulation. Practically all of the floc particles were so large and dense that 97 per cent settled within 3 min. Sedimentation was essentially complete within that time, since only 0.5 per cent additional floc settled in the next 27 min. Final clarity of the supernatant was entirely satisfactory. This coagulation was obtained with a coagulant aid.

Discussion

Research in coagulation very frequently requires observation of the effect of certain variables on the quality of coagulation. Generally, the effects produced by these variables are so subtle that they are not readily observed, and more refined measurements than judgment alone are necessary. The method described has supplied the required objective type of data to enable detection of small differences in a coagulation. Further, it has been possible to run a long series of coagulations investigating perhaps a single variable over a period of a week or more with conclusions on the quality of floc deferred until completion of data collection. Records thus available permanently describe a coagulation in unequivocal terms.

A possible deterrent to more widespread use of this method is the length of time needed to run a series of six coagulations. Although in common practice visual judgment of a series of coagulations may be made during the coagulation and settling period followed perhaps by a single determination of final turbidity, the present method requires additional time to determine turbidity on four or five samples from each jar. These data are then used for calculating and plotting of settling rate curves. This operation adds about an hour's work. The additional time required for each set of coagulations, however, has made possible work which could not have been accomplished as effectively without this method.

Summary

An improved method of jar testing in coagulation work has been pre-

sented which minimizes the need for personal judgment and experience in analyzing the data obtained. Results are reproducible and yield a permanent record for future study. The settling rates obtained describe several important characteristics of a coagulation, including uniformity of floc size, size and denseness of floc particles, and degree of clarification of the water. The settling rate allows detection of small but important differences among coagulations with little additional work. Settling rate determination has provided a valuable analytical tool in research on coagulation, without which some of the work could not have been accomplished.

The author wishes to acknowledge the help of George Rourke, who performed most of the laboratory work, and K. A. Busch, who statistically analyzed the data and aided in the preparation of the section on reproducibility.

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Influence of Bicarbonate Ion on Inhibition of Corrosion by Sodium Silicate in a Zinc-Iron System

Henry L. Shuldener and Leo Lehrman

A contribution to the Journal by Henry L. Shuldener, Pres. and Tech. Director, Water Service Laboratories, Inc., New York, N.Y., and Leo Lehrman, Prof. of Chemistry at the City College of New York, New York City.

ZINC is used as a protective coating for ferrous pipe in two ways—during storage, as a physical barrier to rusting due to contact with moisture and when water is flowing through galvanized piping as a sacrificial metal. Zinc as a protective coating against internal corrosion of water piping, however, has fallen far short of fulfilling its purpose.

In the hot-dip process, layers of zinc-iron alloy are formed close to the iron surface with pure zinc on the outside (*1*). The thickness of the zinc coating varies not only from pipe to pipe, but even on short lengths (6 in. and 14 in.) of the same pipe (*2*). There may be factors, however, such as the composition of the iron or steel, which lead to imperfections in the zinc coating (*1*). Furthermore, certain metals affect the corrosion of zinc; for instance, the presence of 1 per cent or more of tin in the zinc accelerates the corrosive attack by water on the zinc coating (*1, 3*). Bialosky (*4*) says there are conflicting statements as to the protective part the zinc plays, and Uhlig (*5*) states that if there is a small break in the zinc, the iron underneath will rust. Some experimenters believe the zinc gives only temporary protection to the iron until a protective coating of calcium carbonate or corrosion product is deposited (*3, 6, 7*). Haase (*8*) claims zinc is not protective to iron in water and is good only for storage and appearance. Kenworthy and Smith (*9*) show that zinc and zinc-iron alloys act differently; that although zinc protects iron in cold water, it fails to do so in hot water if the iron is exposed. Sereda, Thomas, and Cohen (*10*) state that pitting results when iron is exposed in hot water and that this is an erratic and unpredictable process. They also state that the zinc coating is the initial barrier against pitting, but that the final protection is provided by a scale deposited from the water and which may or may not contain corrosion products.

Effectiveness of Zinc

Thus it appears that zinc gives only temporary protection. Several factors, especially thickness of the zinc layer and the presence of imperfections, play a part in the effectiveness of the zinc. Bialosky (*4*) says that the cause of deterioration of galvanized iron is not thinness of the zinc coat or declining manufacturing skill, but, simply, the hot water. Recently, Evans (*11*) stated

that corrosion of zinc always started locally, as a physical imperfection.

It has been the general concept that the coating of zinc which formed the galvanized layer acted in an electrochemical way to protect the underlying iron or steel (Fig. 1). Schikorr (*12*), however, published data in 1939 to the effect that under certain conditions—especially above 140°F—zinc became cathodic to iron. Later, Roters and Eisenstecken (*13*) showed that zinc becomes cathodic to steel at room temperature, especially in the presence of carbonates. Hoxeng and Prutton (*14*) from the measured potentials of zinc and steel, made separately and in various composition waters at different temperatures, concluded that the "reversal of potential" namely, zinc becoming anodic to iron, depends upon both the water composition and the temperature. They found that, of the two ions which cause reversal in the presence of oxygen—that is, bicarbonate and nitrate—an increase in temperature will increase the probability of reversal by the former but has no effect on the latter. Hoxeng (*15*), in a later publication, showed that chloride, sulfate, calcium, and silicate ions (especially the latter two), shifted the potential of zinc in the anodic direction. He also demonstrated that in the reversal process it is the potential of the zinc that is changing and not that of the iron.

Recently, Guest (*16*) reported reversal of potentials of zinc and steel at 60°, 70°, 80°, and 90°C. It was quickest at 70°C (158°F). It is interesting to note that 160°F was selected for the experiments reported in this article because it was the highest temperature at which reliable and reproducible results could be obtained. Thus it appears that the protection of galvanized piping requires treatment of the water, especially when the water is hot.

Inhibition by Sodium Silicate

Inhibition of corrosion of galvanized piping carrying potable water by continuous introduction of small amounts of sodium silicate (an average of 8 ppm SiO_2) has been successfully carried on for 30 years (*17, 18*). The sodium silicate forms a protective film of initial corrosion products and silica on the surface of the pipe. Denison and Romanoff (*2*) tentatively attribute the high corrosion resistance of galvanized pipe buried in soil to a siliceous film deposited cathodically by galvanic action of the two metals.

Fig. 1. Cleaned Section Galvanized Wrought Iron Hot-Water Pipe

Effect of reversal of potential is shown by extensive areas of galvanizing still present. Arrow points to galvanized layer present up to edge of pit.

In an effort to understand further the mechanism of the inhibition of corrosion by sodium silicate, a study of the effect of some of the components naturally occurring in water was undertaken.

Experimental Procedure

To test corrosion inhibitors rapidly, Ryznar and Green devised a simple apparatus (*19*). They rotate a piece of smooth steel at a known rate (1,750 rpm) for 24 hr in solutions of inhibitors, determining the potential against a standard calomel cell. The effectiveness of the inhibitor is then evaluated from the appearance of the sample and the potential measurements.

The apparatus used in the present work, as shown in Fig. 2 and 3, is a modified form of the Ryznar and Green apparatus. In order better to approximate practical conditions, test pieces were of ¼-in. galvanized pipe, 1.5 in. long, 1 in. of which had twelve 1-mm wide grooves cut through to the steel. The ratio of exposed zinc to iron in the 1-in. length is approximately 1.5:1.

The design of the test pieces was based on two observations of field conditions: [1] The examination of many samples of galvanized piping purchased in the open market revealed skips, flaws, and pits in the galvanizing—that is, the underlying iron surfaces were exposed. Subsequent use of such piping in domestic hot water systems showed that corrosion and pitting were severe where the iron was exposed. This confirms the findings of other workers in this field (*5, 9, 10, 11*).

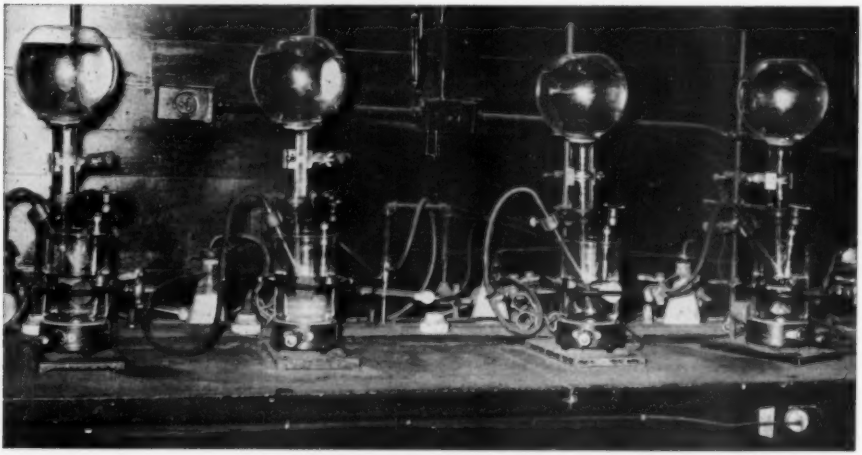

Fig. 2. Apparatus Used in Experiment

[2] Threaded joints of galvanized hot-water piping—where iron surfaces are exposed by removing galvanizing during threading—were most severely affected by corrosion. Both these observations emphasize the fact that, in the corrosion of galvanized piping, there is an iron-zinc bimetallic system to be considered.

A 3-in. length of ¼-in. dowel was inserted in the pipe sample so that its end was flush with the end of the pipe. Both ends of the pipe with the dowel in it, were coated with a water-resistant varnish so that only the outside wall of

the pipe was exposed. The dowel fit into the chuck of the motor so that only 1-in. of the pipe (the grooved portion) was in contact with 600 ml of solution. The motor rotated at 1,750 rpm, which is equivalent to a peripheral velocity of about 1.9 fps. Approximately 1.25 sq in. of metal surface was exposed. The temperature of the solution was kept within ± 2°F by means of a thermostatically controlled heater under the beaker of solution. Carbon dioxide-free air, obtained by passing the air through soda lime, was bubbled into the solution near the rotating specimens but not close enough to have any bubbles impinge on them. A stirring effect was produced by the action of the rotating specimen and by convection currents from the bottom of the beaker. The 2-liter reservoir bottle, containing CO_2-free distilled water was arranged to maintain a constant level in the beaker in order to keep the solute concentration constant. The experiments were run continuously for 4 days, with the solutions changed and analyzed daily and the specimens (Fig. 4) visually inspected for rust with a magnifying glass. Each experiment

TABLE 1

Data From Experiments to Determine Factors Affecting Corrosion of Galvanized Pipe

Experiment	Initial Composition of Water*—*ppm*				pH	Silicate Range *ppm* SiO_2	Number of Days Elapsed When Rust Appeared
	SiO_2	HCO_3^-	Ca^{++}	SO_4^{--}			
1	2.0	4	6	11	7.1		1
2	8.5	4	6	11	8.4	2 – 8.5	—†
3	2.0	14	6	11	7.3		1
4	8.5	14	6	11	8.4	1.5– 7.5	1
5	16.0	14	6	11	9	5 –14.5	4
6‡	8.5	14	6	11	8.4	7.5– 8.5	—†
7§	8.5	14	16	11	8.4	2 – 6.5	1
8‖	8.5	14	16	35	8.4	2 – 8	1–2
9#	8.5	14	6	38	8.4	2 – 7	1
10#	8.5	14	6	51	8.4	1 – 7	1
11**	8.5	14	6	16	7.1	2.5– 8.5	4
12**	8.5	14	6	15	7.5	3 – 8.5	—†
13**	8.5	14	6	14	8	2.5– 6	1
14**	16.0	14	6	15	8	5 –14	1–2
15	8.5	54	6	11	8.4	4 – 7.5	1
16**	8.5	54	6	15	8	4 – 8.5	1
17‡**	8.5	54	6	15	8	7 – 7.5	—†
18	16.0	54	6	11	9	6.5–15.5	1
19‡	16.0	54	6	11	9	11.5–15	—†
20**	8.5	54	6	16	7.5	5 – 9.5	1–2
21**	8.5	54	6	20	7	3.5– 8.5	1–2
22**	8.5	54	6	26	6.5	3 – 8	—†

* Unless otherwise indicated, water used was Catskill water at 160°F.
† No rust apparent after 4 days.
‡ Room temperature (72°F).
§ $CaCl_2$ solution used.
‖ Saturated solution $CaSO_4$ used.
Na_2SO_4 solution used.
** pH adjusted with dilute H_2SO_4.

was run in duplicate. If the results were not consistent, they were repeated twice in duplicate.

The factors affecting the rate of corrosion that were studied in this work were temperature, pH, sodium silicate solution of 1:3.22 ($Na_2O:SiO_2$), bicarbonate ion, calcium ion, and sulfate ion. Table 1 gives the results of the experiments. Table 2 shows an analysis of Catskill water.

Some preliminary experiments showed that maximum corrosion was obtained if ordinary air (containing CO_2) was used. However, in order to be able to control the bicarbonate ion, CO_2-free air was employed.

Results

The experimental data show that silica is always removed from water to which silicate had been added when in contact with iron and zinc, resulting in a deposit on the specimen. Furthermore, the results show that silica is removed from solution whether or not rust is visually apparent. The rate of removal of silica from solution by the specimens decreases with the number of days exposed.

These results confirm those previously found by the authors—namely that silica is taken up by solid corrosion products of the metal to form a protective deposit, and that zinc hydroxide is much more effective than ferric hydroxide in removing silica from water to which small amounts of sodium silicate had been added (*17, 18*). Thus an explanation of the results obtained in the present work becomes evident.

Hoxeng (*15*) had shown that silicate shifts the potential of old zinc in the anodic direction. Where silicate is present the zinc is anodic to the iron, and it corrodes to form zinc hydroxide which adsorbs silica from the silicate solution to form a protective deposit over the whole metal (Experiment 2, Table 1). When bicarbonate is present, especially at higher temperature, Hoxeng showed there is a reversal of the zinc-iron potential. The authors found the same result (Experiment 3,

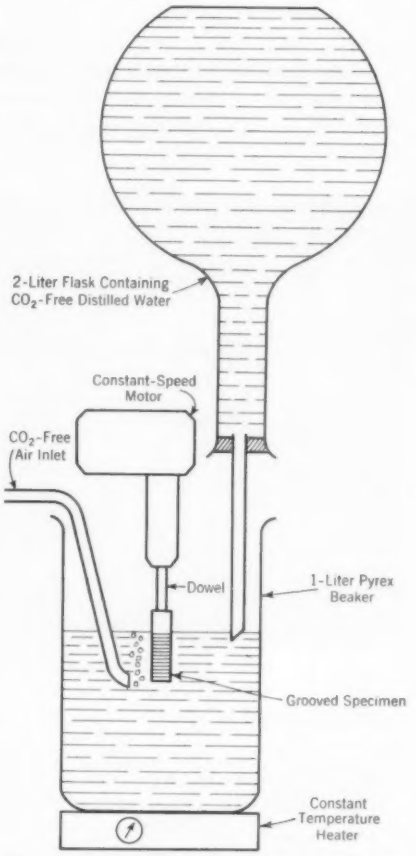

Fig. 3. Diagram of One Unit of Apparatus Shown in Fig. 1

Table 1). Therefore, when both silicate and bicarbonate are present in the solution at higher temperature, two opposing effects take place, the silicate tending to make the zinc anodic to iron and the bicarbonate tending to do the reverse. Thus it appears under these

conditions that the zinc first corrodes to form a zinc corrosion product which removes silica. Probably at some point when the concentration of silicate becomes low enough the reversal takes place with the consequent formation of an iron corrosion product. Because of the lowered concentration of silicate and the slowness with which the iron corrosion product takes up silica from the solution, some rust becomes evident.

Temperature Effect

Temperature effects can be seen from a comparison of Experiments 4 and 6, 16 and 17, and 18 and 19. These show rates of corrosion considerably higher at 160°F than at 72°F, other conditions being the same.

Effect of pH

The effect of pH is shown by comparing Experiments 4 and 13 with 11 and 12; and 15, 16, 20, and 21 with 22. These data show that decreasing the pH from the range of 8.4 and 8 to 7.5 and 7 in the solutions containing sodium silicate (8.5 ppm SiO_2) and bicarbonate (14 ppm HCO_3^-) reduces the rate of corrosion; the same effect is produced when the pH of solutions containing sodium silicate (8.5 ppm SiO_2) and bicarbonate (54 ppm HCO_3^-) is reduced from the range of 8.4 and 7 to 6.5. These results must be considered in the light of the experimental technique—that is, blowing CO_2-free air through a hot solution in open beakers, which undoubtedly removes CO_2 from the solution. As the pH is decreased to below 8.5, the concentration of bicarbonate is decreased as shown in Table 3 (*21*). Although these values were determined at room temperature, it has been assumed for this discussion that the same trend holds for higher temperatures.

Effects of Bicarbonate

As CO_2 is lost the concentration of bicarbonate decreases. A comparison of Experiment 5 with 14 shows that a rise in pH from 8 to 9 decreased the rate of corrosion. It will be noted that as the pH increases in this range the concentration of bicarbonate decreases. Thus it appears that the effect of pH on the corrosion rate is related to the amount of bicarbonate present.

The effect of bicarbonate is closely associated with the pH of the solution. Yet, at all the pH values in this work the concentration of bicarbonate with relation to the concentrations of CO_2 and CO_3 was high. Comparing Experiments 4 and 2 shows that bicarbonate accelerates the rate of corrosion.

Not until the pH is lowered to 7.1–7.5, which decreases the amount of bicarbonate, is the accelerating effect of bicarbonate on corrosion reduced. This is shown in Experiments 11 and 12 as compared with 4.

Furthermore, with a higher concentration of bicarbonate the rate of cor-

TABLE 2

Typical Composition of New York City Water—Catskill Supply *

Constituent	*ppm*
Total hardness ($CaCO_3$)	22
Calcium hardness ($CaCO_3$)	15
Magnesium hardness ($CaCO_3$)	7
Alkalinity, methyl orange ($CaCO_3$)	11
Alkalinity, phenolphthalein ($CaCO_3$)	0
Carbon dioxide (CO_2)	3
Chloride (Cl)	2
Sulfate (SO_4)	11
Silica (SiO_2)	2
pH	7

* Data from work by S. Sussman (*20*).

rosion is higher under the same conditions than with a lower concentration of bicarbonate. (Compare Experiments 20 and 21 with 11 and 12, and Experiment 18 with 5.) With the higher concentration of bicarbonate, when the pH is lowered to below 8.5, again decreasing the concentration of bicarbonate, the rate of corrosion decreases (see Experiment 22).

That it is the bicarbonate which accelerates the rate of corrosion is also shown by the decrease in rate when the pH is raised above 8.5, which also decreases the concentration of bicarbonate. (Compare Experiment 14 with 5.)

It seems quite clear that bicarbonate has a very strong influence in causing reversal of potential and consequent formation of rust at 160°F. This confirms the results of Hoxeng and Prutton (*15*) who used potential measurements in their study.

As previously mentioned, Hoxeng found that sulfate and calcium ions—the latter in the presence of silicate ion especially—tended to shift zinc toward the anodic position with reference to iron. A comparison of Experiments 7,

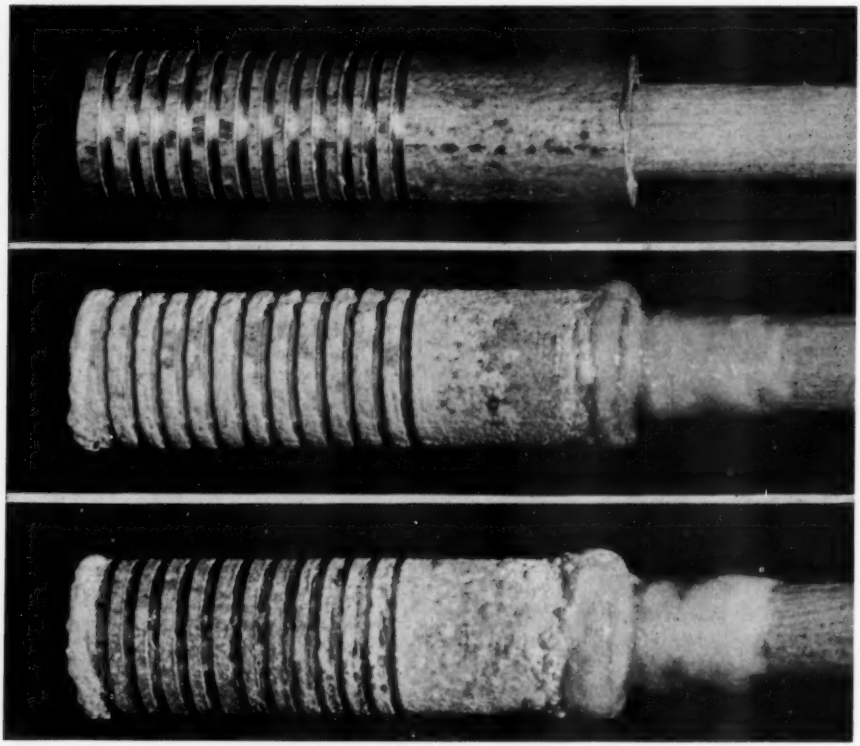

Fig. 4.—Test Pieces Used in Experiment

Original specimen is at top; middle view is after 4 days exposure and shows silica deposits. Bottom specimen shows rust and silica deposits after 4 days exposure.

8, 9, and 10 with 4 shows that neither calcium ion nor sulfate, nor both, in the presence of both silicate and 14 ppm HCO_3^-, had any effect on the corrosion rate.

Effect of Sodium Silicate

The effect of sodium silicate is seen from a comparison of Experiment 11 with 1. Even in the presence of bicarbonate, which has an accelerating effect on the corrosion, sodium silicate (8.5 ppm SiO_2) decreases the corrosion rate at the same pH. Experiments 1 and 2 show that, without considering the effect of pH, sodium silicate inhibits corrosion.

Summary

Rotating galvanized pipe in which grooves had been cut to the underlying iron (producing a zinc-iron couple) at 1,750 rpm (equivalent to about 1.9 fps peripheral velocity) in water solutions through which CO_2-free air is bubbled indicated the following conclusions:

1. An increase from 72°F to 160°F raises the corrosion rate as shown by the rate of formation of rust.
2. Sodium silicate in the solution acts as a corrosion inhibitor and decreases the corrosion rate.
3. Bicarbonate ion causes a reversal of potential with an increase in the corrosion rate of the exposed iron.
4. The pH of the solution, which controls the concentration of the bicarbonate ion, plays an important part in the corrosion rate. (In the pH range 8–8.4 with 14 ppm HCO_3^- and in the presence of 8.5 ppm SiO_2 as sodium silicate, the corrosion rate is at a maximum. At a pH of 8.5 the concentration of bicarbonate ion is at a maximum.)
5. Calcium or sulfate ion or both in the presence of silicate have no effect on the increased corrosion rate caused by the bicarbonate ion.

An explanation is offered for the removal of silica from water to which sodium silicate had been added, which occurred in all the experiments whether or not visual rusting took place.

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TABLE 3

pH and Fraction of Total CO_2 Present†*

pH	H_2CO_3	HCO_3^-	CO_3^{--}
6.0	0.6988	0.3012	0.0000
6.5	0.4232	0.5767	0.0001
7.0	0.1883	0.8113	0.0004
7.5	0.0683	0.9303	0.0014
8.0	0.0226	0.9728	0.0046
8.5	0.0072	0.9783	0.0145
9.0	0.0022	0.9530	0.0448
9.5	0.0006	0.8701	0.1293

* In combined forms shown.
† From ASTM Manual on Industrial Water (*21*).

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Further Study of Solution Effects on Concrete and Cement in Pipe

Martin E. Flentje and Robert J. Sweitzer

A paper presented on May 13, 1957, at the Annual Conference, Atlantic City, N.J., by Martin E. Flentje, Research Engr., American Water Works Service Co., Philadelphia, Pa.; and Robert J. Sweitzer, Director of Research & Development, Lock Joint Pipe Co., East Orange, N.J.

THE first study on solution effects (*1*) presented at the Chicago meeting of the AWWA in 1955 reporting on investigations into the removal of calcium from concrete pipe and cement linings in water supply service concluded:

1. Concrete pressure pipe is only slightly affected by even aggressive water over service periods of 25 years and longer; and, as a result, there has been found no case of failure or even serious damage to concrete pipe attributable to the solution effect of water on the concrete.

2. When new concrete pipe is put into use carrying water, some reaction takes place that soon stops further solution of calcium and leaves the concrete in good condition below a surface layer of from $\frac{1}{32}$ in. to $\frac{3}{32}$ in. in thickness. This reaction as yet is not clearly understood.

3. Further study is needed to determine why concrete resists solution in water works service.

4. Additional study as to the effectiveness of paint seal coats is required before reporting the findings.

This report will cover further investigations into the subject of solution effects of water on concrete and cement in pipe. A method has been devised whereby the extent and depth of calcium removal from concrete pipe can be determined more accurately and the results determined by this method confirm previous conclusions. In addition, the effective service life of paint coatings has been established and some progress made in determining the reason for the cessation of leaching, a phenomenon reported upon earlier.

To establish the depth to which solution of calcium from the concrete had progressed, it was necessary to obtain rather thin layers of material from the concrete specimens to be examined. The removal of the thin, friable layer found on all mains that had been in service was easily accomplished—the removal of subsequent layers was much more difficult. Neither hand scraping nor mechanical removal on a lathe or milling machine was entirely successful, but sectioning representative concrete specimens with a thin, diamond-tipped saw gave samples that were useful both for visual examination and chemical analysis. Figures 1–3 show examples of sectioning done by the saw.

Analysis of Pipe

Three pipe samples were chosen for further study; these were samples from: [1] Portland, Me.—Sample *C*

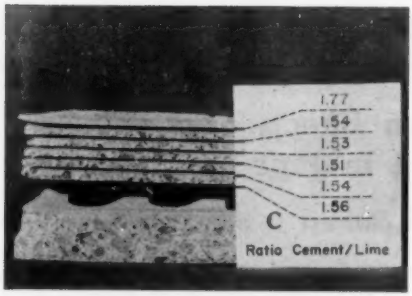

Fig. 1. Pipe Sample From Portland, Me.

of the first report (*1*) and in use for 3 years (Fig. 1); [2] Milton, Pa.—marked *J*—a 16-in., spun, prestressed concrete cylinder pipe line in service 9 years (Fig. 2); and [3] St. Petersburg, Fla.—Sample *B* from the first report (*1*) and 25 years old (Fig. 3). The Portland pipe was exposed to a very soft, low alkalinity, slightly mineralized lake water; the Milton specimen was exposed to a similar soft, unfiltered, mountain water for 9 years with, however, the protection offered by a paint seal coat. The St. Petersburg pipe at the time of sampling, had been in service for 25 years, conveying a quite hard, bicarbonate type, low-incrustant hardness water with a slight negative Langelier Index. The types of water to which the lines from which these samples came were exposed are shown in greater detail in Table 1.

Samples of the inner concrete portion of these pipes were cut into sections of the thicknesses shown in Table 2, which gives the analytical results pertinent to this investigation. The real evidence of possible extraction lies in the cement-lime ratio (Table 3), which has not changed significantly in the samples between the surfaces exposed to water and portions of the pipe wall not directly in contact with water. The ratios in different specimens cannot be compared because the original cement content varied.

The acid-soluble material in the analyses in Table 2 reflects the composition of cement except for the CaO derived from the calcareous aggregate in the St. Petersburg sample. When a correction (*2*) for the calcareous aggregate was applied, data were obtained as shown in Table 3.

These results confirm the earlier conclusion (*1*) that removal of Ca from the inner surface of concrete pipe stops after an initial action on a relatively thin layer of the pipe. Tests indicate this partial loss of Ca is limited to some depth slightly over 0.075 in. and that even in 25 years of service this depth is not greatly nor dangerously exceeded. It is not believed that the aggressiveness of a natural water supply has a great deal to do with the Ca removal phenomenon, except that in a water at the equilibrium point the stabilizing period may be much shorter than in a more aggressive water.

Some examinations have been conducted to determine why the extraction of calcium ceases, and the analytical results indicate an increase in carbonates in the inner layer of the pipe and an increase in the magnesium content. Whether this latter is due to the re-

TABLE 1

Characteristics of Water to Which Pipe Samples Were Exposed

Item	Sample		
	Portland, Me.	Milton, Pa.	St. Petersburg, Fla.
Alkalinity—*ppm*	6.0	10.0	180.0
Total hardness—*ppm*	14.0	10.0	188.0
Calcium (Ca)—*ppm*	4.0	7.0	70.6
Total solids—*ppm*	24.0	19.0	245.0
pH	6.7	6.7	7.5
Saturation index	−3.5	−3.3	−0.2

moval of some of the Ca alone is hard to determine, because of the variable character of the laitance and inner layer of spun pipe and a lack of knowledge of the original composition of the various sections of the pipe.

Samples of the inner and second layers of the Portland pipe were submitted to a laboratory equipped for microscopic, X-ray, and spectrographic analyses. Results of tests on these two sections nearest the water contact are as follows:

On the basis of microscopic, X-ray, and spectrographic examinations and qualitative chemical tests, the ***inner layer*** appears to be composed of a major amount of a calcium-aluminum-silicate mixture, low major amounts of quartz and magnesium silicate, a low minor of calcium carbonate and a trace of magnetic iron oxide.

Spectrographic analysis: Major—calcium, silicon, and magnesium; low major—aluminum; low minor—iron.

As a result of microscopic, X-ray, and spectrographic examinations, the ***next $\frac{1}{8}$-in. layer*** contains a major amount of a calcium-aluminum-silicate mixture, a low major of quartz, a low minor of calcium carbonate, and traces of magnetic iron oxide and calcium hydroxide.

Spectrographic analysis: Major—calcium silicon; low major—aluminum; low minor—iron and magnesium.

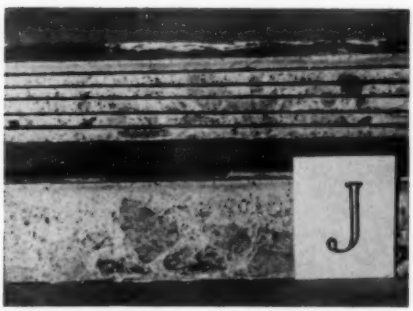

Fig. 2. Pipe Sample From Milton, Pa.

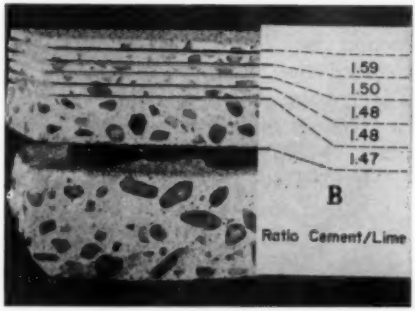

Fig. 3. Pipe Sample From St. Petersburg, Fla.

As the laboratory report shows, the only significant difference between the two samples is the relatively high amount of magnesium in the covering layer on the inside of the pipe. The available evidence indicates that the magnesium is present as magnesium silicate although positive identification of this compound was not obtained. At any rate this point would bear more complete investigation, since magnesium silicate deposition might serve to seal over the concrete and cement and prevent further leaching of the calcium salts.

This suggests that the formation of a magnesium silicate layer or film may be the limiting factor in the continuation of the solution of calcium from concrete. These data resulted in an experiment on a 4-ft length of new 16-in. pipe whereby water containing 300–600 ppm of a magnesium salt was passed under pressure through the pipe. The water used had the following composition before addition of magnesium: total alkalinity, 96 ppm; phenol alkalinity, 0 ppm; CO_2, 0 ppm; total hardness, 80 ppm; Ca, 64 ppm; magnesium, 16 ppm; and pH, 8.0–8.2.

For 5 days of a 12-day period, the high magnesia water was passed through the pipe, and for the balance of the period, the magnesia content was raised to 50 ppm. Then water with

no magnesium was pumped through the section for 24 days at a rate that changed the water once each 24 hr. The average change in water character in parts per million per day was: alkalinity, +1.90; total hardness, −2.20; calcium, −0.40; and magnesium, +300.

Thus, in this particular water, removal of calcium appeared to be stopped or arrested by the magnesium treatment. It was thought that this water was not typical, since it is filtered for iron removal and has pH correction by use of sodium hydroxide. The

TABLE 2

Analysis of Pipe Samples

Item	Dimension of Portion—*in.*					
	Inside 0.075	Next 0.150	Next 0.150	Next 0.150	Next 0.150	Remaining
	Amount—*per cent*					
Portland Sample*						
+100 mesh material	53.0	76.0	80.8	87.6	85.0	85.2
−100 mesh material	47.0	24.0	19.2	12.4	15.0	14.8
Loss at 600°C	10.5	6.0	5.2	4.6	4.2	5.0
Acid soluble (−100 mesh material)						
SiO_2	9.3	10.3	9.4	9.5	10.0	11.3
R_2O_3	8.0	5.5	4.9	4.7	5.2	5.8
CaO	27.8	32.5	29.7	30.7	31.1	33.7
MgO	4.2	1.7	1.5	1.6	1.7	1.8
Total (cement)	49.3	50.0	45.5	46.5	48.0	52.6
Acid insoluble	43.9	45.6	50.1	48.6	47.8	42.9
Loss at 950°C	5.0	3.1	3.2	3.9	3.2	4.1
Total	98.2	98.7	98.8	99.0	99.0	99.6
Milton Sample†						
+20 mesh material	0	13.4	54.1	67.4	63.2	49.4
−20 mesh material	100.0	96.6	45.9	32.6	36.8	50.6
Loss at 600°C	3.1	3.2	3.2	3.2	3.2	4.5
Acid soluble (−20 mesh material)						
SiO_2	16.3	7.4	6.1	5.9	5.9	6.2
R_2O_3	6.7	3.6	2.9	2.7	3.0	3.3
CaO	35.0	17.8	16.8	16.3	15.8	17.5
MgO	4.1	1.6	0.93	0.88	1.0	1.0
Total (cement)	62.1	30.4	26.73	25.78	25.7	28.0
Acid insoluble	31.8	63.8	71.4	72.0	73.5	70.2
Loss at 600°–950°C	5.4	1.7	2.0	1.3	1.5	1.6
Total	99.3	95.9	100.13	99.08	100.7	99.8

* Spun, reinforced pipe, 16-in. diameter, 3-year service.
† Spun, reinforced pipe, 16-in. diameter, 9-year service.

TABLE 2—*Analysis of Pipe Samples (contd.)*

Item	Dimension of Portion—*in.*					
	Inside 0.075	Next 0.150	Next 0.150	Next 0.150	Next 0.150	Remaining
	Amount—*per cent*					
St. Petersburg Sample‡						
+100 mesh material	81.6	91.9	91.2	91.9	92.5	86.4
−100 mesh material	18.4	8.1	8.8	8.1	7.5	13.6
Loss at 600°C	7.8	5.6	5.5	5.0	5.2	5.0
Acid soluble (−100 mesh material)						
SiO_2	7.4	15.2	12.9	14.2	13.6	14.8
R_2O_3	8.0	6.6	4.9	5.4	5.2	6.0
CaO	27.7	43.7	44.3	48.1	46.3	51.4
MgO	5.2	0.76	0.61	0.61	0.52	0.70
Total (cement)	48.4	66.26	62.71	68.31	65.62	72.9
Acid insoluble	39.9	21.7	26.3	20.9	23.3	18.5
Loss at 950°C	12.2	9.4	10.5	9.6	9.8	8.6
Total	100.4	97.36	99.51	98.81	98.72	100.0

‡ Cast pipe, 36-in. diameter, 25-year service.

TABLE 3

Composition of Cement Component in St. Petersburg Sample, and Cement-CaO Ratios

Item	Dimension of Portion—*in.*					
	Inside 0.075	Next 0.150	Next 0.150	Next 0.150	Next 0.150	Remaining
	Amount—*per cent*					
Acid soluble (cement)						
SiO_2	7.4	15.2	12.9	14.2	13.6	14.8
R_2O_3	8.0	6.6	4.9	5.4	5.2	6.0
CaO	16.6	37.9	36.8	42.2	39.9	46.2
MgO	5.2	.76	.61	.61	.52	.70
Total	37.2	60.46	55.21	62.41	59.22	67.70
Acid insoluble	39.9	21.7	26.3	20.9	23.3	18.5
CO_2 in cement	3.5	4.8	4.6	5.0	4.8	4.5
Calcareous aggregate	19.8	10.5	13.4	10.5	11.4	9.3
Total	100.4	97.46	99.51	98.81	98.72	100.0
Cement-CaO Ratio						
Portland, Me.	1.77	1.54	1.53	1.51	1.54	1.56
Milton, Pa.	1.76	1.71	1.59	1.58	1.63	1.60
St. Petersburg, Fla.	2.24	1.59	1.50	1.48	1.48	1.47

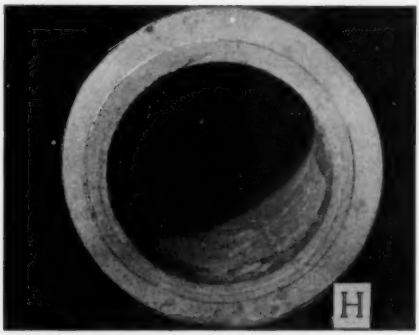

Fig. 4. Pipe Sample From Frenchtown, N.J.

pipe has now been set up in a new location, and water being used in a new test is far more corrosive in that it has a CO_2 content of more than 50 ppm. Data from this series of tests are not yet available.

Effect of Paint Seals

When cement linings for cast-iron pipe were first introduced, it was found that many consumer complaints were received because of hardness, plugging of hot-water coils, and stopped meters. Coating the cement lining with a thin bituminous paint eliminated this trouble to a large extent. The material used serves also to help in the curing of the mortar. P. S. Wilson in a discussion of the earlier report (*1*) has shown this type of material will prevent much of the solution of Ca from the cement, at least for a period of 5–6 years under laboratory conditions.

In this investigation, there was an opportunity to get some data on the length of time such linings effectively protect concrete pipe. The Milton, Pa., pipe sample was coated with a paint seal coating when installed. In 1956, when the specimen examined was taken out of the line, it was determined that approximately one-half the coating was still intact. Approximately 1 mil of paint thickness remained on the interior pipe surface; a normal coat when new consists of 2–2.5 mils. The original paint composition was estimated to be: 50 per cent asphalt base, 45 per cent solvent, and 5 per cent oxidizable oil and carbon filler. The loss of thickness appeared to be due to erosion, since no area of bond failure was found on the sample.

As pointed out earlier, this line carries a soft, slightly acid, unfiltered, mountain stream water. Chemical evidence was obtained in January 1953 that the coating was failing in that some $Ca(OH)_2$ was being dissolved from the line. Unfortunately, no analyses are available between 1948 and 1953. Table 4 shows the data, which indicate a time spread in the solution effects, eliminating objectionable features of early pH and alkalinity pickup.

TABLE 4

*Solution of Ca from Milton Pipeline**

Sampling Point	January 1953		January 1954		August 1954		April 1957	
	Alkalinity *ppm*	pH	Alkalinity *ppm*	pH	Alkalinity *ppm*	pH	Alkalinity *ppm*	pH
At source	6	6.4	6	6.1	7	6.4	5	6.2
Approx. 18,000 ft from source	11	6.8	10	6.3	14	6.7	5	6.2
End of line, 37,000 ft from source	11	6.8	9	6.3	15	6.8	4	6.0

* Pipe installed in June 1948.

TABLE 5

*Effect of Paint Seal on Industrial Pipeline of Westmoreland Authority**

Year	Alkalinity—ppm			pH			Total Hardness—ppm		
	Dam	Plant	Change	Dam	Plant	Change	Dam	Plant	Change
1953	15	18	+3	7.1	7.2	+0.1	105	104	−1
1954	21	22	+1	7.3	7.3	0	105	105	0
1955	4	4	0	6.1	5.9	−0.2	98	102	+4
1956	6	6	0	6.3	6.2	−0.1	102	108	+6
1957	3	4	+1	6.4	6.4	0	98	98	0

* The pipe was placed in service in April 1952. Results are averages of tests made in January and February of each year. The sampling point at the dam is at the entrance to a 42-in. and 30-in. industrial concrete line; the plant sampling point is about 67,000 ft distant.

A somewhat better record is available in an industrial water line at the Municipal Water Authority of Westmoreland County, Pa. This line, about 67,000 ft long, transports raw, impounded, and unfiltered water from Beaver Run Dam. The water is often quite acid and the pH has at times reached a low of 4.4. Hydrated lime, however, was added to bring the pH of the water flowing through the pipe to approximately 6.0.

Results of tests (Table 5) are similar to those obtained at Milton, Pa., and show a decreasing calcium solution rate and finally an almost complete cessation of this phenomenon.

Analysis of Natural Cement

In the course of this investigation, the opportunity presented itself to obtain and examine samples of concrete pipe that, at the time of their removal, had been in service 50 and 75 years respectively. The first of these came from the public supply system of the Frenchtown Water Company, Frenchtown, N.J. This pipe, with a 6-in. inside diameter and approximately $8\frac{11}{16}$-in. outside diameter, was in two sections, separated by a steel cylinder. This pipe has two cylinders as shown in Fig. 4. The second piece of pipe was used for 75 years in the system of the Hingham Water Company, Hingham, Mass. This line was a 4-in. main. It is shown in Fig. 5.

Analysis (Table 6) shows that the cement to CaO ratio of the Frenchtown sample is essentially the same in the exposed layer and the unexposed layer of mortar. The analysis of the Hingham sample (Table 7) indicates some extraction of lime, but Fig. 5 shows the excellent condition of the pipe. Table 8 indicates the characteristics of the water to which these pipes had been exposed.

The analyses given show that the cement used in both of these specimens

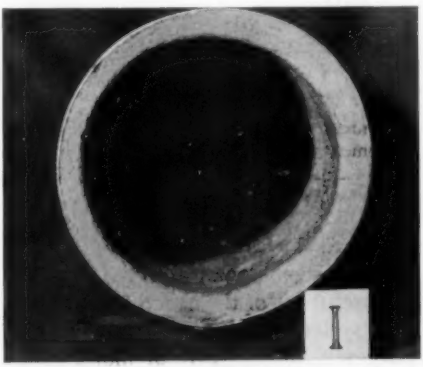

Fig. 5. Pipe Sample From Hingham, Mass.

was natural cement. These are even identifiable as to source. The results also show that removal of Ca was limited to the inner 0.25 in. and 0.20 in. In a valuation study made to establish the accrued depreciation in the facilities of the Frenchtown Water Company, the useful life of the concrete pipe from that system was set, for rate making purposes, at 100 years or more.

Both the Frenchtown and Hingham concrete pipe were made with natural cement. These cements were generally ground more coarsely than in today's practice, and this was the case, also, with Portland cements before the middle 1930's.

That the effect of fineness of grind, particle size, or specific surface could enter into the problem of solution of

TABLE 6

*Analysis of Frenchtown Pipe Sample**

Item	Dimension of Portion—*in.*		
	Inside 0.250	Middle 0.250	Outside 0.500–0.800
	Amount—*per cent*		
+20 mesh material	0	16.9	12.4
−20 mesh material	100.0	83.1	87.6
Loss at 600°C	16.9	19.6	22.5
Acid soluble (−20 mesh material)			
SiO_2	20.2	19.7	19.5
R_2O_3	7.5	6.4	6.9
CaO	29.9	37.9	37.3
MgO	17.0	16.2	16.0
Total (cement)	74.6	80.2	79.7
Acid insoluble	11.2	10.2	9.2
Loss at 600°–950°C	13.6	7.1	9.0
Total	99.4	97.5	97.9
Acid Soluble Portion (Cement) on 100 Per Cent Basis			
SiO_2	27.1	24.5	24.4
R_2O_3	10.1	8.0	8.7
CaO	40.0	47.3	46.8
MgO	22.8	20.2	20.1
Total	100.0	100.0	100.0
Cement Ratios			
Cement to CaO	2.50	2.11	2.14
Cement to MgO	4.39	4.95	4.97

* Pipe in service for 50 years.

CaO from concrete was recognized, and to determine the effect of fineness, a test was set up using four concrete pipes made with two grinds of cement. The first of these consisted of a special grind of Portland cement having a specific surface of 1,215 sq cm per gram, which is representative of older, coarser grinds; the second was a grind having a specific surface of 1,950 sq cm per gram, which is slightly finer than modern grinds. Both samples were made from the same clinker.

TABLE 7

*Analysis of Hingham Pipe Sample**

Item	Dimension of Portion—*in.*	
	Inside 0.200	Outer 0.200
	Amount—*per cent*	
+20 mesh material	5.9	5.4
−20 mesh material	94.1	94.6
Loss at 600°C	10.8	10.8
Acid soluble (−20 mesh material)		
SiO_2	13.7	9.9
R_2O_3	6.8	6.5
CaO	4.9	10.4
MgO	14.5	11.6
Total (cement)	39.9	38.4
Acid insoluble	56.2	55.0
Loss at 600°–950°C	3.9	5.7
Total	100.0	99.1
Acid Soluble Portion (Cement) on 100 Per Cent Basis		
SiO_2	34.3	25.8
R_2O_3	17.1	17.0
CaO	12.2	27.1
MgO	36.3	30.1
Total	99.9	100.0
Cement Ratios		
Cement to CaO	8.16	3.69
Cement to MgO	2.75	3.32

* Pipe in service for 75 years.

TABLE 8

Characteristics of Water to Which Samples Were Exposed

Item	Sample	
	Frenchtown, N. J.	Hingham, Mass.
Alkalinity—*ppm*	106	3
Total hardness—*ppm*	130	12
Chlorides (Cl)—*ppm*	6	8
pH	7.5	6.1

These cements were manufactured into experimental pipe as follows: a pipe was manufactured using coarse ground cement by the poured method of placement of concrete; then, using this same cement, a second pipe was centrifugated. Two similar types of pipe were produced, using the fine ground cement. All mixes were low slump, in the range of 4 in. for cast specimens and with almost no slump for the centrifugated. Test cylinders were manufactured and cured with the pipe, and tested at 7 days, 28 days, 3 months, and 4 months. Two specimens for each grind and type of placement and for each period of curing were tested. For the poured specimens, 6 × 12-in. rodded cylinders were used, and for the centrifugated, 4 × 8-in. vibrated cylinders were used.

Mix design was varied slightly to permit satisfactory manufacture of the specimens by the method used. The cement factor varied from 1.77 bbl per cubic yard to 2.02 bbl per cubic yard. Cylinder strength results are shown in Table 9.

It was then assumed that the average period of time between the manufacture

of pipe and its placement in service in a water system was approximately 4 months. These test specimens were therefore not subjected to calcium oxide extraction tests until they had been held 4 months. The specimens were then flushed and subjected to 31 changes of distilled water over a 3-month period. After each exposure to distilled water, the water was checked for pH, alkalinity, and hardness so that the computation of the pounds of calcium oxide removed from the pipe wall could be made. It was found that in order of the decreasing amount of calcium oxide removed, the pipe behaved as follows: The coarse ground poured pipe suffered a removal of 0.74 lb of calcium oxide; the fine ground poured pipe, 0.70 lb of calcium oxide; coarse ground centrifugated, 0.70 lb; and the fine ground centrifugated, 0.61 lb.

TABLE 9

Test Results on Cylinder Strength

Test Intervals	Fine Ground		Coarse Ground	
	Rodded Cylinder *psi*	Vibrated Cylinder *psi*	Rodded* Cylinder *psi*	Vibrated Cylinder *psi*
7 Days	4,760	6,450	2,970	2,640
28 Days	5,240	7,310	5,270	4,950
3 Months	6,580	8,520	6,590	5,830
4 Months	7,260	8,700	6,290	5,630

It is apparent that there is no appreciable difference in performance with respect to extraction between fine and coarse ground cements, but a change in extraction related to concrete strength is indicated. The pipe manufactured centrifugally, using fine ground cement, obtained a much higher strength than any of the other specimens and suffered the least extraction of CaO.

Based on these tests, there is a possibility that less extraction of CaO in modern pipe can be expected, since the concrete strengths obtained now are far superior to those obtained many years ago. These results point to the conclusion that with all other factors equal, the solution rate is related to concrete strengths and the higher the strength of concrete that is manufactured, the less the solution effect from water will be.

Conclusions

This further work in the investigation of the solution of salts from concrete pipe and concrete and cement pipe linings confirms earlier conclusions.

1. The removal of calcium oxide from such materials is limited to a surface layer something less than 0.25 in. deep, from which decreasing percentages of the total CaO present are removed, going from the water contact outwardly.

2. The reduction in CaO content will not, according to findings, be the controlling factor in the determination of the service life of the pipe.

3. The controlling factor in the solution effect by which CaO is removed from concrete pipe may be the formation of a hindering surface deposit of magnesium silicate and calcium carbonate.

4. Paint coatings such as now commonly used on cement linings and concrete pipe do not, in service, completely protect the pipe from solution effects for a very long time. They do, however, accomplish very satisfactorily their primary purpose of initial protection, and experience indicates mechanical protection lasts over 10 years.

5. There appears to be no difference in the amount of CaO removed in solution from pipe made from either fine

or coarse ground cement. There may be a relationship between concrete strength and CaO solution loss.

6. Pipe manufactured years ago using natural cements for mortar or concrete show service expectancy of greater than 100 years; pipe made using modern methods and materials should exceed this in service life.

Acknowledgments of important assistance, advice, and analytical services are gratefully made to W. J. McCoy, Director of Research, and O. L. Eschenauer, Research Chemist, Lehigh Portland Cement Company; the American Concrete Pressure Pipe Association; and various individual business associates of the authors.

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Correction

The paper "Urban Water Requirements in California" by Max Bookman (August 1957 JOURNAL, Vol. 49, pp. 1053–1059) contained an editorial error. In Fig. 2, on p. 1057, the identification of the horizontal scale is incorrectly given as units of 100,000 acre-ft. The identification should read "Daily Requirements—100 mil gal."

Comparison of Standard Dilution and Membrane Filter Methods

Reginald B. Adams

A paper presented on June 13, 1957, at the Pennsylvania Section Meeting, Bedford, Pa., by Reginald B. Adams, Supt. of Filtration, Wilkinsburg-Penn Joint Water Authority, Wilkinsburg, Pa.

MUCH information has accumulated over the past 10 years in favor of the molecular filter membrane technique (*1–4*). Eliassen (*3*) emphasizes precision as the major advantage of the MF method. It is obvious that the majority of those reporting on studies with the MF method agree that its advantages far outweigh the disadvantages.

Most water works operators are reluctant to drop a standard procedure which has been in use for many years in favor of a completely new technique without first making a comparative study. The purpose of work at Wilkinsburg, Pa., is an attempt to make a comparative study of coliform densities as would be obtained by parallel tests using the standard dilution tube method and the MF method. The entire program has been carried out by regular laboratory personnel.

MPN Method

Lauryl sulfate tryptose broth prepared from dehydrated media was used for the presumptive tests. Five tubes in each of three dilutions were sowed on raw Allegheny River water and prechlorinated raw water. Five 10-ml tubes were sowed on settled basin water. All tubes were read at the end of 24-hr and 48-hr incubation at 35°C. Any presumptive tubes showing gas at the end of 24-hr or 48-hr incubation were withdrawn, and transfers made to 2 per cent brilliant green bile. Brilliant green bile tubes were read at the end of 24-hr and 48-hr incubation, and tubes showing gas at the end of 24 or 48 hr were streaked on Levine's EMB agar. Typical colonies appearing on EMB agar were classified as coliform and these calculated to the MPN per 100 ml.

Volumes of original samples sown into presumptive tubes were pipetted directly when the quantity was 1.0 ml or more; otherwise, dilutions were made to allow transfer of 1.0 ml or more.

MF Method

An endo broth * prepared from dehydrated media was used throughout the study for the MF work. This broth was of special interest, because it entails a one-step procedure as compared to other media requiring an enrichment period and a two-step transfer system.

Selection of sample volume is a matter of prime importance when com-

* M-HD Endo Broth, prepared in accordance with the formula of Hajna and Danon (*5*), and supplied by Difco Laboratories, Inc., Detroit, Mich., and Baltimore Biological Laboratory, Baltimore, Md. A modification of the original formula has recently been developed by Millipore Filter Co., Watertown, Mass.

parative work is undertaken and maximum precision is desired. An attempt was made to select raw-water volumes which would give MF coliform counts in the range of 20–80 colonies. Considerable practice was required to maintain the above range on a majority of the samples, due to the effect of varying amounts of acid mine drainage on the coliform index of the raw water. Results have been most consistent when three different volumes have been sown on each sample of raw water with maximum variation in volume being approximately 1:4. Usually at least two of the three sowings when adjusted to a common factor have given a check count within ± 20 per cent or less. The volumes of raw water actually sown have ranged from 0.1 to 25 ml. The volume of prechlorinated raw water sown has been held at 50 ml and the volume of settled basin water at 100 ml. On a few occasions of heavy runoff the turbidity of the prechlorinated raw water was entirely too high to obtain satisfactory results with a 50-ml sample. Iron and manganese in the prechlorinated raw water usually produce a stain or moderate deposit on the membrane when 50-ml samples are sown. Apparently this condition has not seriously affected the majority of samples.

Volumes of original samples sown were pipetted directly when the quan-

TABLE 1

Comparative Results of Parallel MPN and MF Tests on Raw Allegheny River Water

Month	No. of Samples	No. of Samples in Agreement	No. of Samples in Nonagreement	Agreement* %	Direction of MF Deviation in Nonagreement Samples†
1956					
Apr.	14	12	2	85.7	2+
May	18	14	4	77.7	3+
					1−
Jun.	7	6	1	85.6	1+
Jul.	20	19	1	95.0	1+
Aug.	21	15	6	71.4	3+
					3−
Sep.	19	15	4	78.9	3+
					1−
Oct.	22	18	4	81.7	4+
Nov.	19	15	4	78.9	3+
					1−
Dec.	20	20	0	100.0	—
1957					
Jan.	21	19	2	90.4	2−
Feb.	18	12	6	66.7	1+
					5−
Mar.	20	18	2	90.0	1+
Total	219	183	36		22+
					14−

* Agreement was found in 83.5 per cent of the total samples.
† MF deviation was positive on 10.1 per cent of the total samples and negative on 6.4 per cent.

TABLE 2

Classification of Raw-Water Test Results

Index Range	MPN		MF	
	No. of Samples	Per Cent of Total	No. of Samples	Per Cent of Total
1–99	9	4.1	15	6.9
100–999	56	25.6	51	23.3
1,000–9,999	97	44.3	84	38.3
10,000 and over	57	26.0	69	31.5
Total	219	100.0	219	100.0

tity was 1.0 ml or more; otherwise, dilutions were made to allow transfer of 1.0 ml or more. The same original sample and the same dilutions whenever available were used for both the membrane work and the dilution tube work.

The membranes were placed in disposable plastic petri dishes, and these dishes were incubated in a covered plastic container having a moistened paper towel on the inside bottom for humidity control. The incubation period was 18 ± 2 hr, and the incubation temperature was 35°C.

Colonies showing a golden metallic sheen were counted as typical coliform organisms.

Raw-Water Results

Comparative results of parallel MPN tests and MF tests on 219 samples of raw Allegheny River water for the period Apr. 1, 1956, to Mar. 31, 1957, indicate, as shown in Table 1, 83.5 per cent agreement between the MF and the MPN results. In the above comparison the 95 per cent confidence limit was applied to the MPN results. The nonagreement samples represented 16.5 per cent of the total. Of these, 10.1 per cent represent MF counts which were higher than the corresponding MPN results, and 6.4 per cent represent MF counts which were lower than the corresponding MPN results.

Table 2 indicates the number of samples and the percentage of samples falling within definite coliform index ranges. Table 3 shows comparative averages and medians from various coliform index ranges. It is quite evident that the median MF results tend to run somewhat less than the median MPN results. The relative coliform recovery or the ratio of the median MF to the median MPN was 0.92.

Prechlorinated Water Results

Comparative results of parallel MPN tests and MF tests on prechlorinated water for the period from Apr. 1, 1956, to Mar. 31, 1957, indicate (Table 4) that the MF results show 88.4 per cent agreement with the MPN results in 121 samples which indicated an index of 1.0 or higher on both MPN and MF tests. These 121 samples represented 38.4 per cent of the total 315 examined.

TABLE 3

Comparisons of MPN and MF Results on Raw-Water Tests

Index Range*	Method		$\frac{MF}{MPN}$
	MPN	MF	
Averages			
100–999	460	470	1.02
1,000–9,999	4,300	3,800	0.884
10,000 and over	22,000	23,000	1.05
Medians			
100–999	450	430	0.955
1,000–9,999	3,500	3,200	0.914
10,000 and over	24,000	22,000	0.916

* No figures are available for the range of 1–99, because of insufficient data.

Table 5 shows that 41 per cent or 129 of the *total* samples examined had an apparent index of zero on both the MPN and MF methods; 7.6 per cent (24) had a zero index on MF and an index of 1.0 or more on MPN; and 13 per cent (41) had a zero index on MPN and an index of 1.0 or more on MF. The remaining 38.4 per cent, or 121 of the samples, had an index of 1.0 or more on both the MPN and MF. The latter samples were selected for statistical analysis as they eliminated the problem of handling so many apparent zero results which very likely are not absolute zeros. As with the raw-water tests, the 95 per cent confidence limit was applied to the MPN results.

The nonagreement samples represent 11.6 per cent of the total 121 samples considered for analysis in Table 4. Of these, 4.1 per cent represent MF counts which were higher than the corresponding MPN results, and 7.5 per cent represent MF counts which were lower than the corresponding MPN results. It could be stated that one might expect the MF counts to be in nonagreement in the negative direction on 7.5 per cent of the total samples.

TABLE 4

*Comparative Results of Parallel MPN and MF Tests on Selected Prechlorinated Water Samples**

Month	No. of Samples	No. of Samples in Agreement	No. of Samples in Nonagreement	Agreement† %	Direction of MF Deviation in Nonagreement Samples‡
1956					
Apr.	2	1	1	50.0	1−
May	3	3	0	100.0	—
Jun.	3	3	0	100.0	—
Jul.	0	0	0	—	—
Aug.	4	4	0	100.0	—
Sep.	15	15	0	100.0	—
Oct.	11	9	2	81.8	2−
Nov.	20	18	2	89.9	2−
Dec.	16	15	1	93.7	1−
1957					
Jan.	18	15	3	83.3	2+ 1−
Feb.	10	7	3	70.0	1+ 2−
Mar.	19	17	2	89.4	2+
Total	121	107	14		5+ 9−

* Samples are those showing an index on both MPN and MF tests of 1.0 or higher. Water tested after contact with chlorine for 10 min.

† Agreement was found in 88.4 per cent of the total samples.

‡ MF deviation was positive on 4.1 per cent of the total samples and negative on 7.5 per cent.

Table 6 shows the number of samples falling within definite coliform index ranges and illustrates the tendency for average figures to give a somewhat distorted picture of the median value when the entire series is considered. Exceptions to the above were noted when the series was broken down to defined ranges. The relative coliform recovery or the ratio of the median MF to the median MPN was 0.89.

TABLE 5

Overall Results of Parallel MPN and MF Tests on Prechlorinated Water Samples

Month	Number of Samples				
	Total	Index Range			
		Zero on Both Tests	1.0 or More on Both Tests	1.0 or More on MPN but Zero on MF	1.0 or More on MF but Zero on MPN
1956					
Apr.	16	10	2	1	3
May	31	19	3	1	8
Jun.	16	12	3	0	1
Jul.	28	26	0	0	2
Aug.	26	22	4	0	0
Sep.	27	3	15	2	7
Oct.	28	7	11	6	4
Nov.	30	7	20	1	2
Dec.	28	8	16	4	0
1957					
Jan.	27	3	18	5	1
Feb.	27	8	10	2	7
Mar.	31	4	19	2	6
Total	315	129	121	24	41
Per Cent of Total		41.0	38.4	7.6	13.0

Settled Water Results

Comparative parallel dilution tube tests and MF tests on 315 samples of prechlorinated, coagulated, and settled water for the period from Apr. 1, 1956, to Mar. 31, 1957, produced only two samples that gave a coliform index of 1.0 or more by both methods (Table 7). Thirteen samples had a coliform index of 1.0 or more by MPN and zero coliform index by MF. Eight samples had a coliform index of 1.0 or more by MF and zero index by MPN. Since 92.7 per cent of the samples had an apparent coliform index of zero by both methods, it is indeed difficult to show relative recovery. A glance at the average results per 100 ml would indicate a slightly better recovery for the MPN method. Actually, the major portion of the difference depends upon the interpretation of a few borderline colonies as they appeared on EMB agar. They were late gas formers on both the presumptive and confirmed tests, and had questionable coliform characteristics on EMB agar. They were given the bene-

TABLE 6

*Analysis of Test Results on Selected Samples of Prechlorinated Water**

Item	MPN	MF	$\frac{\text{MF}}{\text{MPN}}$
No. of samples			
1–9 range	94	95	—
10–99 range	27	26	—
Average	7.6	7.8	1.03
Median	4.5	4.0	0.89

* Figures based on 121 samples showing an index range of 1.0 or higher.

fit of doubt and tabulated as coliform. The use of five 10-ml portions did not give the precision required with the multiple-tube method for comparative work, since very low indexes were encountered.

Summary

Parallel MPN tests and MF tests for coliform bacteria were run on 219 samples of raw Allegheny River water covering a period of 1 year. The MF results when compared with the MPN results (95 per cent confidence limit applied) showed 83.5 per cent agreement. The MF results were in nonagreement in the negative direction on 6.4 per cent of the samples. The relative coliform recovery or the ratio of the median MF to the median MPN was 0.92. With adjustment (MPN $\times$ 0.81) for bias (*2*), the relative coliform recovery $\frac{\text{MF}}{\text{MPN}}$ was 1.13.

Parallel MPN tests and MF tests for coliform bacteria were run on 315 samples of prechlorinated Allegheny River water (10 min contact) covering a period of 1 year. The MF results when compared with the MPN results (95% confidence limit applied) showed 88.4 per cent agreement. The MF results were in nonagreement in the negative direction on 7.5 per cent

TABLE 7

Overall Results of Parallel MPN and MF Tests on Prechlorinated, Coagulated, and Settled Water

Month	Number of Samples					Average Index per 100 ml*	
	Total	Index Range				MPN	MF
		Zero on Both Tests	1.0 or More on Both Tests	1.0 or More on MPN but Zero on MF	1.0 or More on MF but Zero on MPN		
1956							
Apr.	16	15	0	0	1	0.00	0.06
May	31	29	0	1	1	0.03	0.03
Jun.	16	16	0	0	0	0.00	0.00
Jul.	28	27	0	0	0	0.00	0.07
Aug.	26	26	0	0	0	0.00	0.00
Sep.	27	23	0	3	1	0.40	0.10
Oct.	28	27	0	1	0	0.06	0.00
Nov.	30	29	0	1	0	0.07	0.00
Dec.	28	26	0	1	1	0.07	0.03
1957							
Jan.	27	23	0	1	3	0.07	0.37
Feb.	27	26	0	1	0	0.28	0.00
Mar.	31	25	2	4	0	0.47	0.07
Total	315	292	2	13	8		
Per Cent of Total		92.7	0.6	4.1	2.6		

* Overall averages for the 315 samples were 0.14 for MPN and 0.07 for MF.

of the samples. The relative coliform recovery $\frac{MF}{MPN}$ equaled 0.89. With adjustment for bias ($MPN \times 0.81$), the relative coliform recovery $\frac{MF}{MPN}$ was 1.10.

Parallel MPN tests and MF tests for coliform bacteria were run on 315 samples of prechlorinated, coagulated, and settled water covering a period of 1 year. Statistical analysis was not applicable, due to the relatively few samples showing coliform organisms. The average results, if they may be treated with any significance, indicate slightly better recovery with MPN than with MF. The major difference, however, hinges on the interpretation of a few of the MPN tests and the low precision evident on very low indexes using five 10-ml portions. For all practical purposes both methods gave nearly equivalent coliform indexes.

From the above data the conclusion is that the MF technique using an endo broth in a one-step transfer system has given coliform densities comparable to those obtained with multiple-dilution tubes.

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Recent Meter-setting Developments

Panel Discussion

A panel discussion presented on May 16, 1957, at the Annual Conference, Atlantic City, N.J.

Introduction—*W. Victor Weir*

An introductory statement by W. Victor Weir, Pres. and Gen. Mgr., St. Louis County Water Co. and Missouri Water Co., University City, Mo.

THE problems of setting water meters—where and how—are not critical industry problems. They are, however, present in every water utility operation. Policy decisions affecting both the utility and its customers must be made. These are local decisions; what is correct for one utility may be entirely wrong for another.

The largest problem involves the location of the meters—should they be in the customers' residences and places of business or should they be in vaults or box settings near the property lines? Although a utility may adopt a general policy, there may be circumstances that justify an exception to the general rule. What are the circumstances that determine the general policy and also the exceptions? The following discussions will cover the economic aspects, ease of obtaining readings, considerations of safety, differences in maintenance costs, cold weather problems, and the factor of customer annoyance.

Another phase of meter-setting problems involves the use or nonuse of meter-holding devices. Many of these are available, some simple, others complicated. Where and when should they be used?

Outside settings involve underground vaults of varying sizes, depending upon the sizes of the meters that must be set. Proper design of these facilities brings lowest costs of installation, maintenance, and reading, and minimizes the hazards to the public. What factors should determine the design standards for a utility?

The problem of a single large meter or a battery of smaller meters presents questions that extend into the field of meter-setting problems. A battery setting is actually an assembled compound meter setting that involves more vault space than would be required for a compound meter of equal capacity.

This discussion of meter-setting problems must necessarily be based upon the types of meters generally available today. If and when the water meter industry develops different meters or the utilities adopt meters with remote registers, some of which are available today, there may be different meter-setting problems. Those, however, must be left for future discussion.

—Indoor or Outdoor Installation?—*James G. Carns Jr.*—

A paper presented by James G. Carns Jr., Meter Engr., American Water Works Service Co., Philadelphia, Pa.

The ever increasing difficulty of gaining admission to properties to read meters and the fact that the cost of meter reading in outdoor installations is less than that for indoor installations are two important factors to be considered in arriving at a decision on meter location. The belief, however, that savings in reading costs will offset higher installation costs for outdoor settings, at the same time overcoming reading difficulties, is one which needs to be explored further.

Meter Location

Generally speaking, a choice between indoor and outdoor installations is not available in southern states, where, because of mild winter weather, most homes are constructed without basements or utility rooms and water meters must be installed in outdoor pits or vaults. Conversely, in many of the northern states, although the majority of homes are constructed with basements and a choice of meter locations exists, severe winter weather conditions weigh heavily against outdoor installations, and the logical indoor location is most often utilized. There is, however, a large, undefined geographic belt between these two extremes where a choice of meter location exists.

Evaluation of Advantages

Unfortunately, it is very difficult to evaluate effectively the relative advantages and disadvantages of both meter locations by any means other than actual expenrience over an extended period. This advantage is seldom available, however, before sizable expenditures have been made. Even then, operating expense data are usually not kept in sufficient detail to afford the opportunity of making a factual comparison of costs. For example, water utilities which follow the uniform system of accounts for water utilities as adopted by National Association of Railroad and Utilities Commissioners do not, unless certain modifications are made, have data in suitable detail for cost studies of various phases of operating and maintenance expenses. This is particularly true of expenses involving meter and meter installation maintenance costs. The uniform system of accounts provides that the installed cost of meters or devices and appurtenances thereto for use in measuring the quantity of water delivered to customers is to be charged to Utility Plant Account 324—*Meters*. Instructions for this system further state that the cost of testing and maintaining meters and related devices and appurtenances, the book cost of which is included in Utility Plant Account 324, is to be charged to Account 759.2—*Maintenance of Meters*. Unless, therefore, subaccounts are used to separate meter and meter installation maintenance costs, it is not possible to determine either of these expenses individually. In the company with which the author is associated, a breakdown of these expenses has been maintained since Jul. 1, 1948, for 63 separate water companies operating in twenty states, mainly east of the Mississippi River. They are thereby able to determine not only average meter-reading costs each year but also the average cost of repairing and testing meters and meter installations. Thirteen of the 63 companies have made all

meter installations in outdoor settings for many years and each now has 90 per cent or more of all meters in service (a total of 274,000) in outdoor settings. The other 50 companies, with approximately 427,000 meters, follow the practice of installing meters indoors wherever possible, but have a minor percentage of outdoor settings.

Although the segregation of meter and meter installation maintenance costs was made primarily to obtain average meter repair cost data, it has also been valuable in determining the economics involved in the location of meters. It is, of course, essential in presenting the results of any study also to detail the manner by which such results are produced, if conclusions drawn are to have any real value. The following, therefore, will explain how the results of a 5-year comparison of reading costs for the thirteen companies with outdoor settings and the 50 with indoor settings have been obtained. All companies, of course, followed the same accounting procedures and system of records.

Cost of Reading

The cost of all labor, transportation, and supplies involved in reading meters is charged to Account 781.3—*Meter Reading*. These costs include all those incurred in obtaining readings for billing purposes, but do not include the cost of readings or inspections made for other reasons, such as high-bill complaints, the costs of which are charged to various other expense accounts depending on the purpose for which they are made. The total of metered bills rendered each year is obtained from bill proof sheets and this number is considered as the number of meter readings obtained during the year. The average number of metered accounts billed is 1/12 the number of monthly accounts plus 1/4 the number of quarterly accounts billed each year. The average cost per reading is obtained by dividing the total charges to meter reading expense each year by the number of metered bills rendered.

Maintenance

Total labor, material, and other costs incurred in repairing and testing meters are charged to Account 759.2—*Meter Maintenance*. These charges include all expenses incurred in testing or repairing meters, either in the meter shop or in service. They do not, however, include the cost of changing meters. The average cost per meter repaired or tested each year is obtained by dividing the total charges to meter maintenance by the number of meters repaired or tested during the year. The cost of repairing and testing meters is not pertinent to this analysis.

All expenses incurred in maintaining meter installations are charged to Account 759.7—*Meter Installations Maintenance*.

Table 1 shows the average cost per reading considering only actual reading costs. It will be noted that the cost per reading for outdoor settings runs rather consistently about 2/3 of that for indoor settings. This not only confirms what is generally known or surmised, but actually shows how much less reading costs are with outdoor settings. Although these results may seem to show a smaller cost difference than other reading cost comparisons, this may result from the fact that this study includes nonproductive expenses properly attributed to but often neglected in short-term meter reading cost studies, such as sick and vacation pay of meter readers and numerous miscellaneous items of expense.

Experience shows that there is a much larger maintenance cost for

meter installations when meters are installed in outdoor settings. For example, in 1954, when the number of outdoor settings in thirteen companies was 273,987 or 39 per cent of the total of 701,338 for all 63 companies studied, meter installation maintenance cost for these 13 companies was 79.2 per cent of the total. Also, a large portion of this expense for the other 50 companies is due to maintaining outdoor settings. consideration is given also to meter installation maintenance costs. This is shown by the fact that for the 5-year period, while total meter reading costs for the 13 companies with outdoor settings was $501,029, meter installations maintenance costs for the same period totaled $337,349, which is 67 per cent of the cost of reading. During the same 5-year period, the reading costs for the other 50 companies totaled

TABLE 1

Meter Reading Costs for 63 Companies, 1950–54

Year	Average Number Metered Accounts Billed	Total Number Metered Bills Rendered	Total Reading Costs	Average Cost Per Reading
		Outdoor Installations*		
1950	231,320	1,077,178	$ 79,466.64	$0.074
1951	241,149	1,123,972	92,969.97	0.083
1952	251,227	1,177,257	99,138.60	0.084
1953	262,233	1,226,105	109,699.59	0.089
1954	273,987	1,275,884	119,754.57	0.094
		Indoor Installations†		
1950	373,735	1,605,946	$180,529.37	0.112
1951	387,232	1,660,755	206,941.82	0.125
1952	399,174	1,710,279	234,537.02	0.137
1953	414,616	1,772,573	255,446.20	0.144
1954	427,351	1,824,574	271,582.08	0.149

* Thirteen companies; 90–100 per cent outdoor installations.
† Fifty companies with a minor number of outdoor installations.

The amount is indeterminate, however. In a comparison of costs such as presented here, which shows a reduction in reading costs while other costs are increased—due to installing meters in outdoor settings—it seems only fair to combine such costs to arrive at a proper comparison of all costs involved. Table 2 shows the result when this is done.

From this tabulation, it is found that there is very little difference in total expense due to meter location when $1,149,036, whereas installation maintenance costs were only $96,875 or 8.5 per cent of reading costs.

Although the causes for maintenance of both types of installations are fairly obvious the total cost of maintaining outdoor settings is not generally recognized. It has been found that the only maintenance required for indoor settings consists of replacement of broken meter couplings or those with stripped threads and the cost of repairing piping connections or fittings adjacent to the

meter. These occurrences are very infrequent in relation to the number of installations and, for all practical purposes, maintenance costs for indoor meter installations are negligible.

With outdoor settings, however, there are a number of maintenance items and the frequency of occurrence is such that the aggregate cost is a major expense item. The major maintenance needs are:

1. Filling around meter boxes where dirt has been washed away by heavy rains
2. Raising and lowering meter boxes to conform to changes of grade
3. Replacing broken meter box covers and repairing other damage to the installations caused by automobiles, trucks, or heavy construction equipment (This type of damage may be particularly extensive in new developments where the meter installations are made before curbs, sidewalks, and street paving have been installed. It is particularly difficult to minimize.)
4. Corrective measures to avoid meter damage due to freezing.

All four types of maintenance are inherent and must be expected when meters are installed in outdoor settings. It may be argued that if the original installations are properly designed and made, corrective measures against freezing should not be necessary. This is true, but, from a practical standpoint, meters will freeze in varying numbers during extremely cold spells even in the "best regulated families." The trick is to design an installation which will afford adequate frost protection under all types of weather and soil conditions and not be excessive in cost. A particular type of setting designed to accomplish this is usually adopted and used throughout an entire service

TABLE 2

Meter Reading and Maintenance Costs for Same Companies and Periods Shown in Table 1

Year	Average Number Metered Accounts Billed	Total Number Metered Bills Rendered	Total Reading Costs	Total Meter Installation Maintenance Costs	Total Reading and Installation Maintenance Costs	Average Cost Per Reading (Including Maintenance)
			Outdoor Installations			
1950	231,320	1,077,178	$ 79,466.64	$52,644.33	$132,110.97	$0.123
1951	241,149	1,123,972	92,969.97	57,228.81	150,198.78	0.134
1952	251,227	1,177,257	99,138.60	64,139.86	163,278.46	0.139
1953	262,233	1,226,105	109,699.59	79,287.18	188,986.77	0.154
1954	273,987	1,275,884	119,754.57	84,048.82	203,803.39	0.160
			Indoor Installations			
1950	373,735	1,605,946	$180,529.37	$18,546.79	$199,076.16	0.124
1951	387,232	1,660,755	206,941.82	19,796.02	226,737.84	0.137
1952	399,174	1,710,279	234,537.02	17,115.18	251,652.20	0.147
1953	414,616	1,772,573	255,446.20	19,352.93	274,799.13	0.155
1954	427,351	1,824,574	271,582.08	22,063.64	293,645.72	0.161

area. During extremely cold winters, however, it is often found that sufficient protection is not obtained in all installations and a number of meters freeze. This may be caused by the fact that installations are in sandy or gravelly soil which frost penetrates faster than heavier, more compact types of soil. Often, meters will freeze in otherwise suitable installations only because the soil around the pit was not compacted during backfilling operations. Unfortunately, each installation cannot be individually tailored for soil conditions encountered. Even were such attempt to be made, there is probably no one with sufficient knowledge of this subject to do so with complete success.

Many water utilities, for several years installed outdoor settings which were thought to be adequate, only to find during extremely severe winters that inadequate protection against freezing conditions was afforded. Many expedients have been tried, some successfully, to correct the deficient conditions without complete replacement of the installations. Some of these consist of inserting an inner lid in each meter pit to reduce heat loss; placing sawdust or other materials in the pits to insulate the meter; replacing the soil around the pits to varying depths with material of greater density, such as clay or loam to reduce frost penetration; and installing smaller diameter tile in the bottom of pits to obtain heat from the ground at a lower level and counteract the colder upper portions of the pit in contact with the frozen ground.

The only obvious conclusion which can be reached from an analysis of this type is that the benefit of lower reading costs with outdoor meter settings is dissipated through increased installation maintenance costs. It would appear, therefore, that decisions on meter location should discount meter reading savings as a major factor.

Advantages of Outdoor Setting

Thus far only the disadvantages of outdoor meter settings have been mentioned. There are, of course, several advantages which should be considered. In addition to making possible readings on scheduled dates, there is no need for the utility employee to enter the customer's premises. Anyone who has read meters and had a housewife, who had come down from the second floor to let him in, watch while he made wet, muddy tracks across a freshly cleaned kitchen floor can well appreciate that customer's feelings toward the utility. This, of course, is the customer relation side of the picture. Another factor in favor of curb settings is that the meter is located at the division point of service responsibility so that any leakage in the customer's portion of the service line is measured. Although an attempt has been made to evaluate this factor, unaccounted for water has so many aspects to be considered that results have been inconclusive. The question of tampering with meters is fairly well resolved with outdoor settings as the privacy necessary for tampering is lacking. It must also be recognized that there are maintenance charges in connection with curb boxes which have not been accounted for in the cost comparisons cited and which would, if known, tend to influence the results in favor of outdoor meter settings. Finally, meters have been known to freeze when installed indoors, so that this difficulty is not limited to outdoor settings.

Limitations

Outdoor meter settings for large accounts, such as schools, apartments, business buildings, and other commer-

cial and industrial accounts, however, should be avoided wherever possible because of the high cost of such installations and because the benefits to be derived cannot possibly be justified from an economic standpoint.

When consideration is given to the numerous and potentially costly expenses which may be sustained with outdoor settings, the difficulties attendant to gaining admission to properties to read meters usually lose much of their significance. Several measures have been tried to overcome the difficulty of obtaining readings with indoor settings. The most common is for the meter reader to leave self-addressed postcards at properties to which they are unable to gain admission. These cards inform the occupant of the reader's visit, continue with a request for the owner or occupant to read the meter, and, using the postcard notice, to forward the reading promptly to the water utility office. In many instances, excellent response is had with this method. Of course, there is also the practice of detailing a reader for calls in the evening.

Some utilities have a rule whereby back calls are made only to read those meters from which a reading was not obtained for the previous billing period. Average bills are sent for the rest of the accounts where meters were not read. This procedure has the advantage of reducing the number of back calls and provides more time for obtaining readings of those accounts which have not been read for two or more consecutive reading periods.

Another means used when readings have not been obtained consists in sending the customer an average bill which is higher than usual, increasing the amount with each successive reading period until a complaint is made, at which time arrangements are made to obtain a reading. This procedure is usually reserved for extreme situations.

Reduction in Reading Cost

For those who are interested and have sufficient cost figures to work with, it is relatively easy to determine how much additional investment can be made for an outdoor setting to obtain a given reduction in reading cost. Any cost above this figure is a premium being paid for the outdoor setting. Referring to Table 1, the average cost to read meters for 1954 is: outdoor, $0.094; indoor $0.149. With an account billed quarterly, the saving in reading cost is four times $0.055 or $0.22 per year. Assuming the cost of borrowed money to be 5 per cent, this $0.22 per year saving will support an additional investment of $4.40. If the cost of installing a meter in an outdoor setting is more than $4.40 over that for an indoor setting, the installation is not economically justified. Using the results produced when installation maintenance expenses are combined with reading costs (Table 2), it is apparent that no additional cost for outdoor installations can be made if economic balance is to be maintained.

Philadelphia—*Gerald E. Arnold*

A paper presented by Gerald E. Arnold, Gen. Supt., Water Dept., Philadelphia, Pa.

In Philadelphia, there are comparatively few outside meter settings. Nearly all residences and business establishments have basements, and it has been common practice for many years to bring the service pipe into the base-

ment and set the meter as near as possible to where the service pipe enters. There are admittedly some disadvantages to inside settings, the principal one being the necessity for entrance into the property in order to read or service the meter. There are, however, also advantages to inside settings. One is the comparative freedom from freezing which can result in damage when meters are installed in improperly protected exterior meter boxes or vaults. There has been some difficulty in Philadelphia with flooded meter boxes or vaults from ground water seepage or storm drainage. When such situations are encountered by the meter readers, the property owner or tenant is required to pump out the meter box or vault at his expense, which almost always results in a second call to the premises to read the meter. The standard practice in Philadelphia, when houses are built without basements, is to bring water service up through the floor slab into the service room where the water meter, furnace, and hot-water heater are located above floor level. When there is snow on the ground, it is difficult to locate meter boxes or vaults unless the meter reader is very familiar with each location. For this reason, the few meters in Philadelphia that are located outside, are customarily read when there is no snow on the ground.

The whole question of inside and outside settings has many points worthy of consideration, and the determination should be made in accordance with climatic and other local conditions. The question of the depth of the meter setting within the meter box or vault is really one of frost penetration and coldness of the climate. With small meters, an elevating yoke is satisfactory for bringing the meter to the upper part of the meter box and seems to prevent freezing—except in extreme cases. For large meters, the expense of additional piping does not justify raising the meter within the vault. In Philadelphia, the water department does not install any portion of the service line or meter box and, therefore, is not liable if it is defective. This, however, is an important problem in some cities, as a damaged or missing meter box cover could result in an injury and subsequent damage claim. Most cities are particularly diligent about keeping meter box covers in place and in good condition.

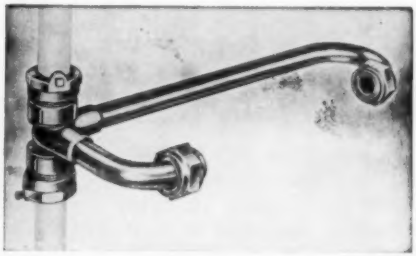

Fig. 1. Meter Horn Installed in Iron Pipe

Horn is type used at Philadelphia. Set screw shown has square head rather than Allen head mentioned in text.

Use of Meter Yoke

A point of importance to consider with meter setting is the use of a meter horn or yoke to hold the meter in proper position and to relieve the meter of strain if the piping moves. In connection with the universal metering program in Philadelphia, use of a horn was prescribed for all universal meter installations. The new service rules and regulations for the water department will require the use of a horn or a similar device for all new meter installations. The horn used * (Fig. 1)

* The Kornerhorn, a product of the Ford Meter Box Co., Inc., Wabash, Ind.

in the universal metering program was equipped with compression couplings which permitted its installation on existing piping without threading the pipe or, with copper tubing, by soldering. The installation of this horn is very simple and quick; it is necessary to make only two cuts in the pipe, remove the short section, place the compression couplings over the cut ends of the pipe, place the horn, and tighten the couplings. To hold the coupling in place, an Allen-head screw was used on iron pipe, and a split clamp attached to the coupling on copper pipe. The specifications for these horns required that they withstand a pull of 300 lb, for the ¾-in. size, without slipping.

Advantages

The use of a horn or yoke with or without compression couplings has several distinct advantages. One is that it holds the piping firmly in place when the meter is removed, making it possible for one man to remove and replace meters in a relatively short time. It also eliminates the danger of breaking of the pipe at a nearby joint or coupling and reduces the likelihood of leaks occurring after the meter has been removed or replaced. The use of the horn or yoke also provides a continuous bond in the water piping preventing electrical shock to the meter installer. There have been occasions when meter installers, removing an old meter from a line without a horn or yoke, have, on touching both sides of the meter couplings, received a shock from improperly grounded electrical fixtures in the premises. To avoid this type of accident meter installers have been equipped with a heavy copper wire fitted with clips which are attached to the pipe on both sides of the meter before its removal. This provides the necessary bond through the pipe to avoid shock to the installer. When a horn is used, a wire clip device of this type is not necessary. Permanent grounding wires around meters are not standard practice in Philadelphia. As long as the meter is connected to the piping, it provides the necessary metallic bond. The use of the portable wire and clips described above provides the necessary ground and protects the meter installer when he removes the meter and breaks the normal circuit. This is one of the big advantages of a horn or yoke—it always provides continuous metallic grounding. The specifications for horns and yokes in Philadelphia requires that they have a resistance to electrical flow of not more than 0.5 ohm.

Another advantage of the horn is that distortion or moving of the piping within the premises will not place any undue strain on the meter or the meter couplings. The use of a horn also makes it possible to install the meter in the proper position in a vertical pipe without the necessity of using short-radius elbows or nipples for connecting piping to the meter. These elbows or nipples introduce a very high head loss in the flowing water.

When meters are installed on old piping, it is highly desirable to install a horn or yoke and replace the meter with a spacer or nipple in the horn. This allows the customer to use water for several days before the meter is installed, producing a thorough flushing of the piping and removing any scale or cuttings from the pipe which may otherwise be caught in the meter. By following this principal of thorough flushing before installation, it was possible to install more than 150,000 meters in older residences in Philadelphia without experiencing a single case of meter jammed by material dislodged from the piping. The additional cost

of the horn is a relatively minor item when a complete meter installation is being made, and it is felt that the additional cost is well justified for better service and fewer complaints and difficulties.

Position

The author has had no experience in Philadelphia with meters set in any but a horizontal position. It is understood that all manufacturers recommend that their meters be installed in this position, and the basic design of the meter is for horizontal installation. Disc meters will operate in any position, but use in other than horizontal position may result in excessive wear and inaccuracies at the low flow rates. End bushings in both the register and the gear train are not effective in preventing wear of the spindles when the meter is changed to any other position. If the meters are to be operated in a vertical position, suitable bearings should be designed and incorporated to take the wear points for this type of operation. With the ball sockets, which would wear eccentrically in a vertical setting, there will be a tendency for the disc to rub one wall of the chamber and to have excess clearance on the other wall, which would result in inaccuracies at the low flow rates. The author has started a series of tests on meters set in the vertical position, but further time will be required to complete them.

Compound Meters

Compound meters are better for large services than batteries of smaller meters. In order to obtain accuracy at the low flows with a battery of small meters, it would be necessary to have a device which would divert all of the flow through one meter at times of low consumption, to take advantage of the low-flow accuracy of such a meter. For example, a 2-in. disc meter has a minimum flow test rate of 2 gpm, at which point it must be accurate within 95 per cent. The series of six 2-in. meters, which would be required for an equivalent 6-in. service, would result in flows below the minimum accuracy requirements at a flow rate less than 12 gpm. The 6-in. compound meter, equipped with a 1-in. bypass meter, would have an accuracy of 95 per cent with a flow rate of only 0.75 gpm. Another factor involving batteries of meters, is the inability of meters to take the flows evenly because of hydraulic flow conditions. In other words, one meter operates a great deal of the time while another meter in the battery operates at high flow rates only, resulting in uneven wear between the meters in a single battery. The expense of installation of a battery of meters is considerably higher because of the necessity of fabricating the manifold to accommodate several meters and there is the additional expense of connections, valves, and fittings to be considered. Another important factor is the space requirement. A 6-in. compound meter is about 18×36 in., which, together with the fittings, requires a vault approximately 4×6 ft. Six 2-in. disc meters, to accomplish the same purpose, would require a vault not less than 5×15 ft, or more than three times the total area needed for a compound meter. In a 10-in. service, a vault 4×8 ft would accommodate the compound meter, but a vault 5×30 ft or 10×15 ft would be necessary to accommodate the fifteen 2-in. disc meters necessary for this service. The head loss through the two types of meters is about the same, but the additional head loss required for

connections, valves, and fittings would increase the total head loss of the installation for battery meters.

With regard to maintenance and repairs, compound meters generally take fewer, less costly repair parts than a corresponding battery of smaller meters.

Crews

The use of one- or two-man crews for installation of meters is governed by several factors—the basic one of which is travel time between calls. Where a number of calls can be made in one block or within a short travel distance, two men can quite efficiently perform the work, and, in the event one of them has difficulty, he can call his partner to assist him. Where the calls are widely spaced, and appreciable travel time is necessary, better efficiency results from the use of one man.

Conclusion

Many of the comments made above are variable from city to city, and are governed by climatic conditions, geography, density of population, condition of piping, age of meters and other factors. No firm set of rules can be considered universal in general metering practice.

Richmond, Va.—*Marsden C. Smith*

A paper presented by Marsden C. Smith, Chief Water Engr., Dept. of Public Utilities, Richmond, Va.

It can be truly said that water utilities need nothing so much as improved meters. The electric utilities' small, weather-proof glass cylinder which can be "tacked up" at eye level and replaced as easily as pulling an electric cord, offers a strong contrast to water meters now available which are a problem no matter where placed.

Until a water meter is developed with features that approach those of the electric meter, it must be realized that the problem of setting meters is of great importance and complexity.

This author is neither for nor against either inside or outside meter settings, but intends simply to present the facts of improved outside meter settings that have been found to be of great help in reducing meter problems.

Since freezing of meters is rarely a problem in Richmond, all meters have always been set in boxes or vaults outside of buildings, except in those rare cases in which an inside setting can be had that is readily available for reading and in which the special circumstances accompanying repairs are adequately provided for.

Until recently no one has cared to eliminate the causes of serious complaints by those who must read and maintain meters which have been set without consideration for their comfort and even safety. For example, the ¾- and 1-in. meter settings and boxes required the repairman or meter setter, when working, to sprawl in the mud, dirt, or snow, and to have need of three hands where at best only two could reach. This difficulty is greatly lessened by the use of copper setters which, by raising the meter, both simplify reading and usually place the meter above the water and muck so frequently found in meter boxes. The use of lipped nuts

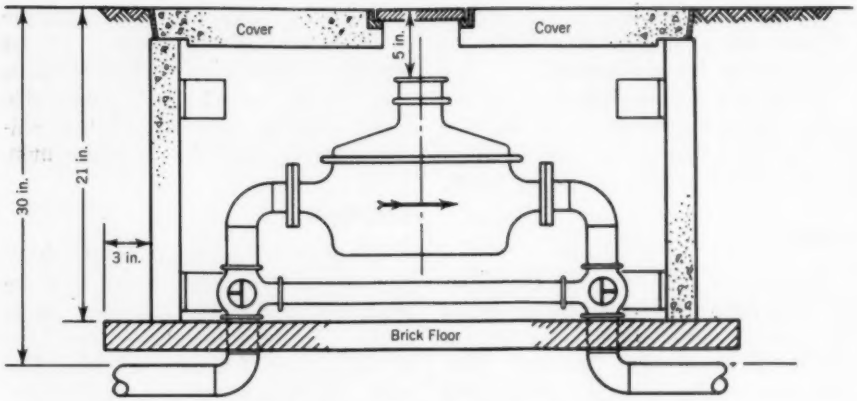

Fig. 2. Side View of 1½- and 2-in. Disc Meter Setting

on the copper setters materially reduces the difficulty of connecting a meter in the copper setter.

Meter Enclosures

It was the haphazard enclosures or vaults that were used for meters of 1.5 in. size and larger that were truly inexcusable. These, excessively costly to build, were always damp and slimy—often actually unfit places for human beings to work. Head room was frequently inadequate because of drainage problems and, when the entrance was made large enough to permit reasonably free access to the vault, the covers became so heavy that two men were required for meter reading. Furthermore, many covers were rectangular and meters were often damaged or destroyed by covers falling into the vault.

New Designs

Recently adopted standard settings for all meters and detector checks—both singly and in combination—now

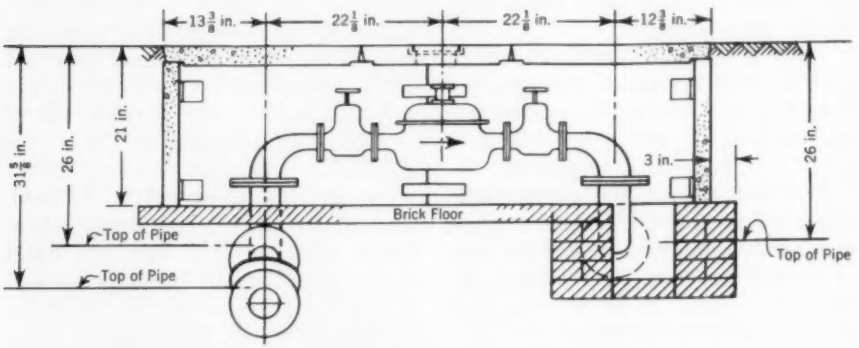

Fig. 3. Dual 2-in. Disc Meter Setting

Dual 2-in. disc is used in place of 3-in. compound meter.

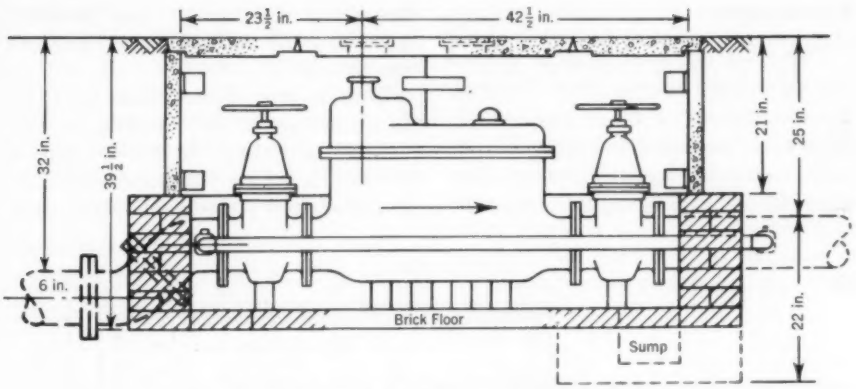

Fig. 4. Setting for a 6-in. Compound Meter

eliminate most of the serious disadvantages of the outside meter settings formerly used. It is these new designs that, it is believed, will be of interest. Use has demonstrated them to be as nearly the ideal as can be had so long as the style of meters now available remains the same.

Although not required because of frost penetration, all service pipes must have 30 in. of cover in order to be below the thick street paving on arterial streets. Because of this it has been found advisable to use the two 45-deg bends on the inlet side of the large meters in order to bring the meter parts closer to the surface for ease of reading and maintenance.

All vaults are now built with standard parts which are so designed as to permit the fabrication of vaults for all 1.5-in. and larger meters and combinations and still require a minimum number of different pieces in stock.

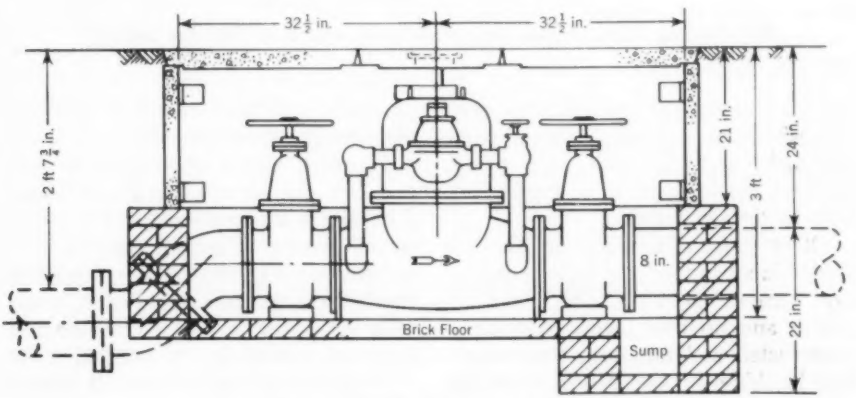

Fig. 5. Eight-Inch Detector Check

Advantages

There are many advantages derived from this construction: with the reading opening only 5 in. in diameter, its lid is easily removed and replaced; the vault cover, in single or multiple sections, is easily removed for meter repairs permitting the repairman to work in fresh air, uncramped; tools and parts are easily accessible and, as a result, time needed for reading or repairs has been materially reduced.

Other great advantages are that no skilled labor is used for their construction because the vaults are bolted together and no roof forms have to be constructed and removed, thus reducing blocking of the sidewalk during concrete pouring and setting. Lastly, the cost of the average vault has been reduced from approximately $300 to less than $100.

Thus, by a small investment in effort, the most important objections to outside meter settings have been almost eliminated. The public reaction has been especially pleasing and many compliments have been received since the new designs were adopted.

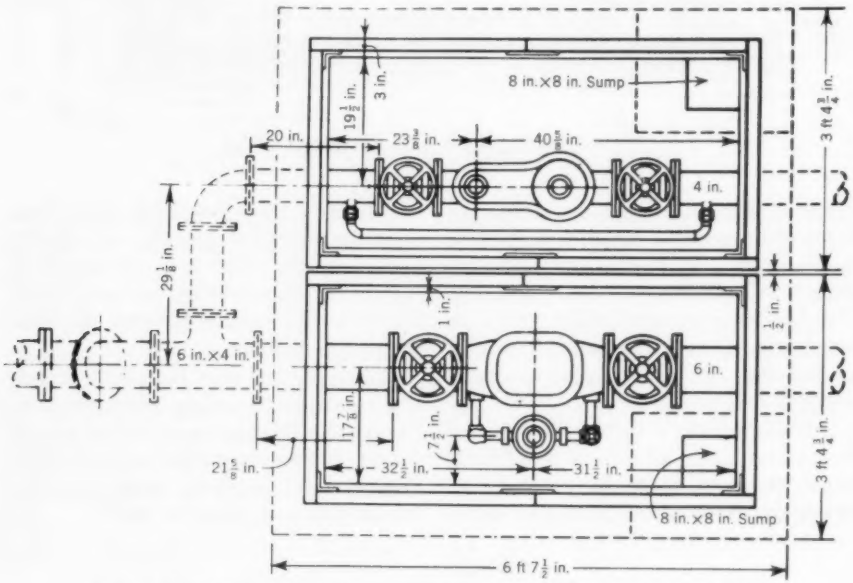

Fig. 6. Top View of 4-in. Compound Meter and 6-in. Detector Setting

Figure 2 shows the setting of 1.5- and 2-in. disc meters. In Fig. 3 a dual 2-in. disc is used rather than 3-in. compound meters. Figure 4 shows a 6-in. compound; Fig. 5, an 8-in. detector check for fire lines; and Fig. 6, a top view of a 4-in. compound meter setting with a 6-in. detector check.

It should be noted that all meters 1.5 in. and larger are provided with

bypasses. These are sealed and normally inaccessible, but when the vault covers are removed, they can be reached easily for operation. These bypasses are a valuable addition to the design because they permit repair or even exchange of meters without serious inconvenience to the customer.

Unsolved Problems

Obviously, the problems resulting from meters being occasionally submerged where storm sewers are not readily available remains a serious objection to outside meter settings. In addition, the necessity for special provisions to prevent moisture accumulation and fogging of the dial glass cover still exists in damp locations. But even these difficulties can be eliminated when there is a sufficient demand to warrant the development expense of dials which may be placed remote from the meter.

Ottawa—*W. Elwood MacDonald*

A paper presented by W. Elwood MacDonald, Comr. of Water Works, Water Works Dept., Ottawa, Ont.

The ideal setting of a water meter is in a meter chamber at or near the property line. Installations of this kind provide a return to the water works organization for all water consumption on the premises of the owner.

As has been noted, however, the location of a meter is first dependent on the local climatic conditions.

Conditions at Ottawa

Ottawa, situated in eastern Ontario at a latitude of 45 deg. has temperatures which vary from 98°F in the summer to a minimum in the winter months of about −38°F. The temperature of the water throughout the distribution system ranges from 84°F to 33°F.

An accurate record of the degree days of frost is maintained annually in Ottawa. This record consists of the cumulative total of degrees below freezing—the difference between the mean daily temperature and 32°F, without reduction for days when the mean temperature is above the freezing point. The statistical information compiled on the above basis from 1932 to 1955 inclusive shows an annual average of 1,720 degree days, with a high of 2,854.5 in 1933–34, and a low of 788.0 in 1932–33. This record is maintained as a guide to determine the severity of the winter in relation to frost penetration in the soil.

In 1947, a study of frost penetration was made for the city by Robert F. Legget (*1*) of the National Research Council of Canada. As a result of intensive studies, he concluded, with respect to the conditions existing in the city of Ottawa, that: ". . . if 500 or more degree days occur before the end of December in Ottawa, some consideration should be given to restrict the snow plowing in areas where water pipes are vulnerable."

Meter Installation

Early in 1953, in response to an extension of city boundaries, the water department undertook the installation of approximately 40,000 meters at an

estimated cost of $1,250,000. Before beginning the actual work of installation, the department first carried out an intensive study of the various methods of meter installation, particularly of the smaller sizes, with a view to determining the most efficient method at the lowest cost. With a few exceptions, installation within the buildings was adopted as standard practice largely in consideration of the severity

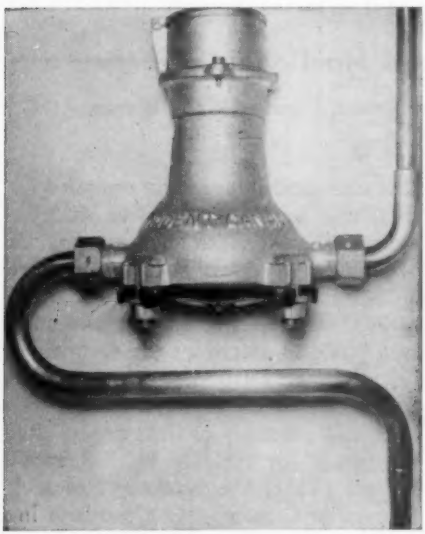

Fig. 7. MacDonald Meter Setting on Copper Service

of the winters in Ottawa. The bylaws of the corporation provide that the owner or tenant shall give every aid in the installation and protection of such water meters.

Preliminary Survey

Before actual installation, a preliminary survey was carried out to determine the location of the meter. It must be close to the point where the water service enters the building and so placed as to register all the water consumed within the building.

Interior Installation

It has been found after several years that installation of meters within buildings is the only practical method which can be followed in this city. The advantages of interior installation in this northern climate are:

1. Installation can be made during winter or summer under very favorable working conditions.
2. Readings can be obtained, generally, without delay.

TABLE 3

Installation Costs With New Type Meter Setting

Item	Copper Pipe	Iron Pipe
Labor	$2.75	$2.75
New type meter setting	1.75	1.95
Total	4.50	4.70

3. Testing of meters can be carried out under excellent working conditions.
4. The meters can be removed and a new meter reset within a minimum time.
5. A greater number of meters can be read daily without snow removal during the winter season.

Special Installations

Certain situations exist, however—due to the extreme setback of buildings, with intervening connections between the street line and the building proper—where it is not expedient to install meters within the buildings. In installations of this kind, the remote locations of the buildings require that me-

ters be installed close to the property line. In such installations, the meters are installed in chambers approximately 8 ft below the surface. These meter chambers are filled with an insulating material (mineral wool) to prevent damage to the meters by frost.

Installation Costs

Before proceeding with the installation of meters, plans and specifications were prepared and tenders invited covering installation of small-size meters. These tenders were for installation only, exclusive of all materials. The prices included the installation in accordance with the conventional method of using the usual straight tail pieces with nipples and four 90-deg bends, and ranged from a high of $32 to a low of $10 per installation.

The labor cost involved using the conventional method was entirely too high and, after considerable research, the author designed and had manufactured a new type of meter setting (Fig. 7). This new device is now available in both Canada and the United States. It is entirely different from any meter setting on the market and will permit substantial savings in the installation of $\frac{5}{8}$-, $\frac{5}{8} \times \frac{3}{4}$- and $\frac{3}{4}$-in. meters.

The actual cost of meter installation by city crews using the new type of meter setting, for a $\frac{5}{8}$-in. meter is shown in Table 3.

To date, approximately 28,000 $\frac{5}{8}$-, $\frac{5}{8} \times \frac{3}{4}$-, and $\frac{3}{4}$-in. meters have been installed using this meter setting. Approximately 26,000 $\frac{5}{8}$-in. meters have been installed at a unit saving of $2.96 compared to the cost with the conventional method. This represents an actual saving to the municipality of $75,000.

Large-Size Settings

All meters 1.5–2 in. in size are installed in the conventional manner and are removed to the meter testing laboratory when testing is required. All meters 4 in. in size and over are installed with a bypass; with a test T and valve; and with valves before the meter, after the test T, and on the bypass. In this way, meters can be removed for repairs or other necessary work without interfering with the supply of water to the consumer, and they can be tested in place by using the test T and field apparatus. If the meters are installed in a building, there is no particular need of a chamber. If the meter is outside a building, however, a reinforced concrete chamber is constructed as shown in Fig. 8.

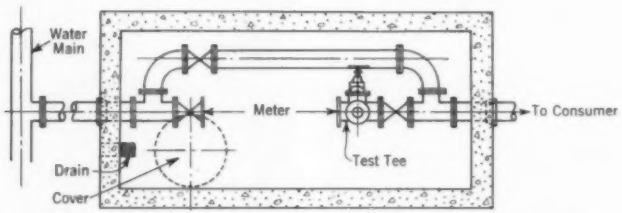

Fig. 8. Typical Installation for 4-in. (and Over) Meters

Methods of Reading

To facilitate the reading of water meters an arrangement was completed approximately 3 years ago with the Ottawa Hydroelectric Commission under which that organization reads all electric and water meters simultaneously.

This method is working out most satisfactorily and is heartily endorsed by all tenants and homeowners as it reduces the number of annual meter readings by half. The cost of reading water meters in Ottawa in 1956 was 12.434 cents per reading.

The actual readings are recorded in the meter readers' books on site and are transferred daily, using the mark sense method, to cards which are processed and billed by appropriate business machines.

Meter Insulation

Where indications point to a temperature below 30°F within any building, special precautions are taken by the department to install around the meter a protective insulating device. This device consists of a specially designed wooden box which is fitted securely to the special type meter setting used in Ottawa (Fig. 9). The

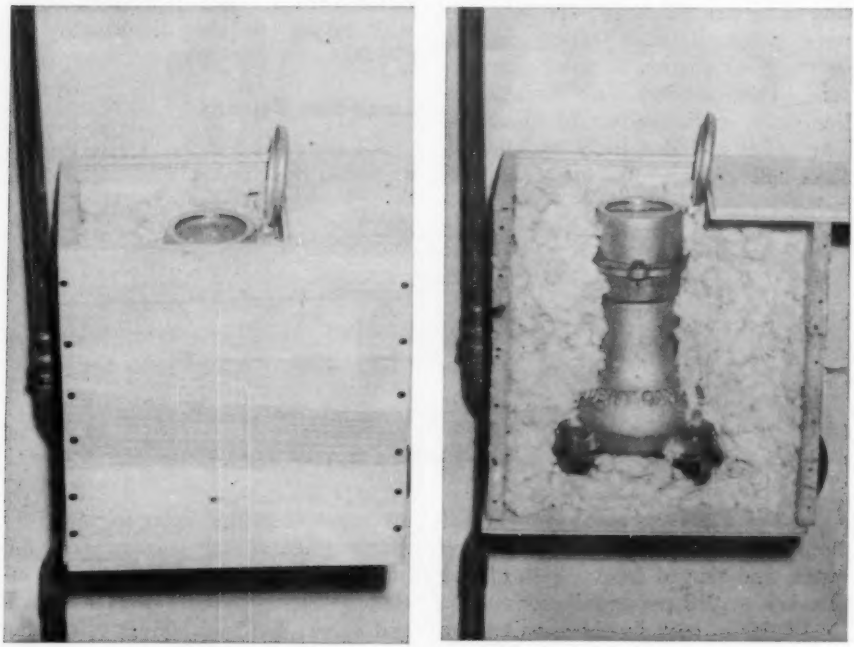

Fig. 9. Meter Insulating Box

Left view shows complete box; right, one side removed, with mineral wool exposed. Sliding top panel is open in both views.

meter, in the center of the box, is protected from frost by mineral wool. To facilitate reading, each box is equipped with a sliding top panel. The insulating units can be installed on the $\frac{5}{8} \times \frac{3}{4}$-in. size for $1.50 per unit.

During the past severe winter, 478 meters were frozen; only seven of these were meters protected by the special insulation box.

Reference

1. LEGGETT, R. F. & CRAWFORD, C. B. Soil Temperatures in Water Works Practice. *Jour. AWWA,* **44**:10 (Oct. 1952).

Correction

The paper "Experimental Evaluation of 'Water Conditioner' Performance" by Rolf Eliassen and Rolf T. Skrinde (September 1957 JOURNAL, Vol. 49, pp. 1179–1190) contained an error. The charts for Fig. 10 and 11 (pp. 1188 and 1189) were transposed. The drawing that appears on p. 1189 should appear as Fig. 10, "Effect of Evis Treatment on Solubility of Scale" (p. 1188); likewise, the drawing that appears on p. 1188 should appear as Fig. 11, "Effect of Evis Treatment on Filtration of Calcium Carbonate Solution" (p. 1189).

Status of Fluoridation in the United States and Canada, 1956

Task Group Report

A report of Task Group 2620 P—Fluoridation Materials and Methods, submitted by Robert S. Phillips (Chairman), Asst. Supt., Charlotte Water Dept., Charlotte, N.C. Other members of the task group are R. L. Derby, H. A. Faber, A. E. Griffin, L. E. Harper, W. L. Harris, F. J. Maier, O. J. Muegge, R. W. Ockershausen, R. C. Pickard, F. S. Taylor, H. W. Tracy, D. B. Williams, and J. C. Zufelt.

THE fluoridation of public water supplies for the prevention of dental caries continued to show steady growth in North America during 1956. Two hundred and thirteen communities in the United States and seven municipalities in Canada instituted the controlled addition of fluoride compounds to water supplies during the year.

By the end of the year nearly 1,500 communities in the United States were furnishing fluoridated water to a population of 31,416,112 persons. This represents a growth of nearly 27 per cent when compared with the population served at the end of the previous year. In Canada the rate of growth was almost as great. By the end of 1956, 25 Canadian municipalities, serving a population of 890,450 persons, were adding fluorides to the water supplies. Table 1 and Fig. 1 shows the progress which has been made since 1945.

In the United States the growth in fluoridation was generally consistent in cities and towns of all sizes. By the end of 1956 more than 28 per cent of the communities having a population of 10,000 or more were being served fluoridated water (Table 2 and Fig. 2).

During 1956, Chicago, the second largest city in the United States, began to fluoridate its water supply. With the beginning of this installation, ten of the fifteen largest cities in the United States (1950 populations) were adding fluorides to their water supplies. These cities are Chicago, Philadelphia, Baltimore, Cleveland, St. Louis, Washington, San Francisco, Pittsburgh, Milwaukee, and Buffalo. Two other cities, Los Angeles and Houston, have water supplies in which fluorides occur naturally. The remaining three largest cities not fluoridating are Boston, Detroit, and New York City.

During 1956 fluoridation was discontinued by twelve water supplies in the United States serving a population of 184,546 persons. This loss was considerably smaller than in either 1955 or 1954, when populations of 394,040 and 1,069,875 were affected. Since 1945, however, only about 6 per cent of the total population served has been involved in the discontinuances. In addition, it should be pointed out that ten water supply systems have reinstituted fluoridation since 1945, four of which resumed operations during 1956 (Table 3).

TABLE 1

Growth of Fluoridation in the United States and Canada, 1945–56 *

End of Year	United States			Canada	
	Number of Water Systems Using Fluoridation	Number of Communities Served	Population Served	Number of Water Systems Using Fluoridation	Population Served
1945	3	6	231,920	1	50,600
1946	8	12	332,467	1	50,600
1947	11	16	458,748	1	50,600
1948	13	24	581,683	1	50,600
1949	29	46	1,062,779	1	50,600
1950	62	95	1,578,578	1	50,600
1951	171	329	4,948,259	1	50,600
1952	353	709	13,552,501	6	160,150
1953	482	949	17,080,930	8	209,800
1954	571	1,128	21,208,304	9	220,800
1955	667	1,274	24,775,698	18	731,600
1956	759	1,487	31,416,112	25	890,450

* Revised data courtesy of US Public Health Service.

TABLE 2

Distribution, by Population Segment, of United States Communities Using Fluoridation, Dec. 31, 1956 *

Population Segment	Number of Communities†	Communities Using Controlled Fluoridation	
		Number	Percentage of Population Segment
1,000,000 and over	5	2	40.0
500,000–999,999	13	8	61.5
250,000–499,999	23	7	30.4
100,000–249,999	65	19	29.2
50,000– 99,999	126	42	33.3
25,000– 49,999	252	78	31.0
10,000– 24,999	778	201	25.8
5,000– 9,999	1,176	209	17.8
2,500– 4,999	1,846	251	13.6
1,000– 2,499	4,296	277	6.4
Under 1,000, and not specified	9,968	393	3.9
Total	18,548	1,487	8.0

* Data furnished by US Public Health Service.
† Source: Statistical Abstract, US Bureau of the Census, Department of Commerce, 1955.

TABLE 3

Fluoridation Installations Instituted, Discontinued, and Reinstituted 1945–56 *

Year	Fluoridation Instituted†		Fluoridation Discontinued‡		Fluoridation Reinstituted	
	Number of Water Supply Systems	Population Served	Number of Water Supply Systems	Population Served	Number of Water Supply Systems	Population Served
1945	3	231,920				
1946	5	100,547				
1947	3	126,281				
1948	2	122,935				
1949	16	481,096				
1950	34	532,349	1	16,550		
1951	110	3,382,581	1	12,900		
1952	187	8,776,914	5	172,672		
1953	134	3,413,579	7	51,616	2	166,466
1954	107	5,193,315	20	1,069,875	2	3,934
1955	112	3,947,462	18	394,040	2	13,972
1956	100	6,786,591	12	184,546	4	38,369

* Revised data furnished by US Public Health Service.
† Total, whether or not discontinued.
‡ Total, whether or not reinstituted.

TABLE 4

Distribution of Ownership of Supply and Agency Authorizing Fluoridation, Dec. 31, 1956 *

Population Segment	Number of Communities	Ownership			Authorization			
		Public	Private	Other and Not Specified	Governing Body Alone	Referendum	Utilities Commission	Other and Not Specified
1,000,000 and over	2	2			2			
500,000–999,999	8	8			7	1		
250,000–499,999	7	6	1		7			
100,000–249,999	19	17	2		17			2
50,000– 99,999	42	36	6		39	1		2
25,000– 49,999	78	70	7	1	70	2	2	4
10,000– 24,999	201	180	15	6	173	12	5	11
5,000– 9,999	209	177	30	2	180	10	1	18
2,500– 4,999	251	214	28	9	208	9	6	28
1,000– 2,499	277	235	35	7	233	9	10	25
Under 1,000	190	148	42		168	9	4	9
Not specified	203	179	24		148	24	28	3
Total	1,487	1,272	190	25	1,252	77	56	102

* Data furnished by US Public Health Service.

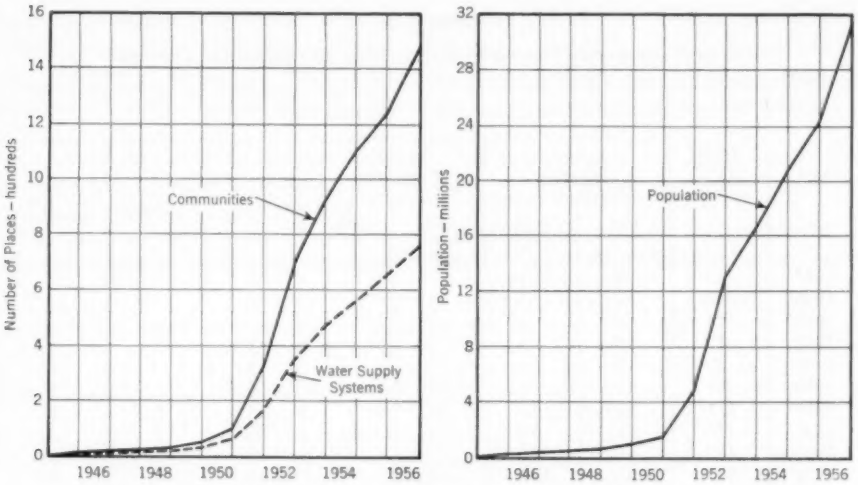

Fig. 1. US Communities, Water Supply Systems, and Population Furnished With Fluoridated Water, 1945–56

Communities obtaining fluoridated water from publicly owned water supplies in the United States number 1,272. This is somewhat more than 85 per cent of the total number of all communities using fluoridated water. Authorization for the institution of fluoridation was given by the governing body in more than 84 per cent of the communities. Only about 5 per cent of the cities or towns obtained authorization by referendum. The percentages differ very little from the previous report (Table 4).

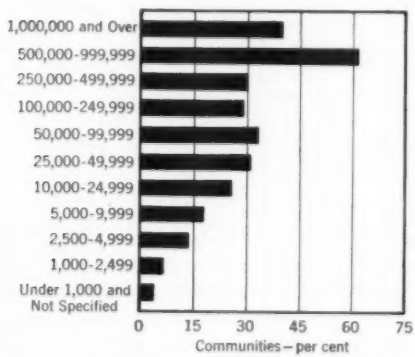

Fig. 2. Percentage of US Communities, by Population Segment, Using Fluoridation, Dec. 31, 1956

Fluoridation Chemicals

Sodium silicofluoride continues to be the chemical of choice by more than one half of the water supply systems. Sodium fluoride is the second choice, and is used by about one-third of the water supply systems. Consistent gains have been shown each year since 1949 in the use of fluosilicic acid as a fluoridation chemical. There has been no change reported in the number of places using ammonium fluosilicate since 1954. Tables 5–7 and Fig. 3 give the pertinent data.

The use of fluorspar for fluoridating the water supply at Belair, Md., was reported by Maier and Bellack (*1*). A special dissolver utilizing an aluminum salt for dissolving the fluorspar was

TABLE 5

Use by Water Supply Systems of Various Fluorine Compounds, 1945–56 *

Year	Total Water Supply Systems	Chemical Used						
		Sodium Fluoride		Sodium Silicofluoride		Fluosilicic Acid	Ammonium Fluosilicate	Other and Not Specified
		Dry Feed	Soln. Feed	Dry Feed	Soln. Feed			
1945	3	2	1					
1946	8	4	3	1				
1947	11	5	4	2				
1948	13	5	5	2		1		
1949	29	9	10	8		1		1
1950	62	12	21	24		3		2
1951	171	29	43	77		18	1	3
1952	353	51	85	176	3	33	2	3
1953	482	61	120	246	7	39	3	6
1954	571	68	136	298	7	48	5	9
1955	667	83	161	336	12	57	5	13
1956	759	94	181	369	14	63	5	33

* Revised data courtesy of US Public Health Service.

TABLE 6

Annual Cumulative Population Provided With Fluoridated Water, According to Chemical Used, 1945–56 *

Year	Total Population	Chemical				
		Sodium Fluoride	Sodium Silicofluoride	Fluosilicic Acid	Ammonium Fluosilicate	Other and Not Specified
1945	231,920	231,920				
1946	332,467	315,747	16,720			
1947	458,748	428,028	30,720			
1948	581,683	430,963	30,720	120,000		
1949	1,062,779	840,225	96,274	120,000		6,280
1950	1,578,578	990,764	376,211	200,774		10,829
1951	4,948,259	1,386,189	3,245,020	302,109	4,112	10,829
1952	13,552,501	2,532,941	9,261,172	1,740,447	7,112	10,829
1953	17,080,930	3,003,621	12,066,458	1,815,939	9,612	185,300
1954	21,208,304	2,755,175	14,104,679	4,038,105	59,621	250,724
1955	24,775,698	3,527,862	15,929,206	4,980,228	59,621	278,781
1956	31,416,112	3,699,295	17,655,643	9,574,672	59,621	426,881

* Revised data courtesy of US Public Health Service.

used to produce a saturated fluoride solution and a fixed aluminum salt solution. These solutions are utilized for coagulation and fluoridation of the water.

Contrary to 1955 (*2*), there were no important shortages of fluoridating chemicals reported during the year.

Despite the fact that the vast majority of fluoridation installations are operated with only minor problems, the committee has received reports from time to time on more severe difficulties experienced by operators in connection with the use of the chemicals. In order to evaluate these reports more fully, a subcommittee under the chairmanship of A. E. Griffin has been formed. AWWA members are requested to report any unusual difficulties to this subcommittee for further study.

Fluoride Kit Study

A study of permanent color comparators for measuring fluoride concentrations was completed by the committee during the year. Franz J. Maier was chairman of the task group, consisting of personnel from five laboratories which cooperated in the study. The report of the work has been published in the *Journal* (*3*).

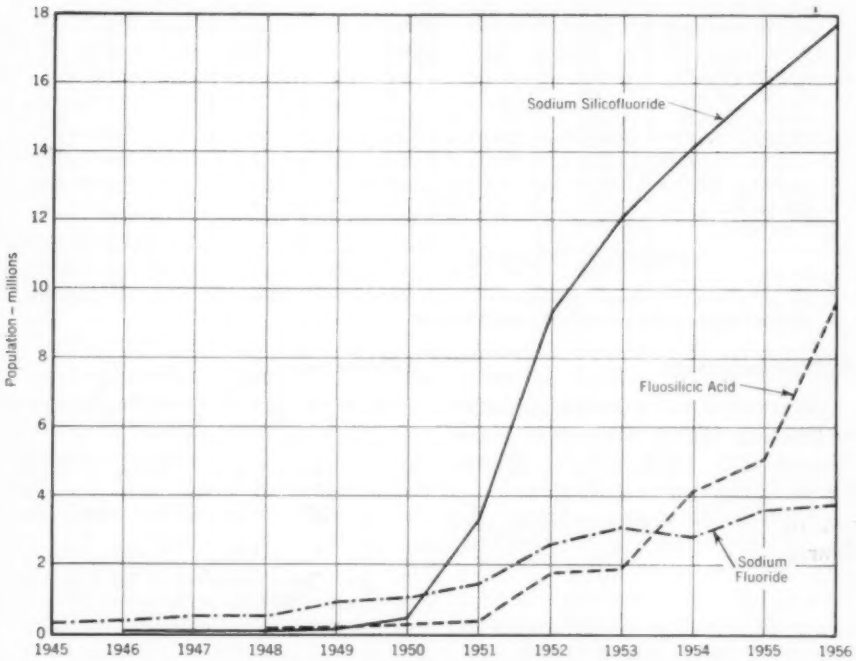

Fig. 3. Cumulative US Population Provided With Fluoridated Water, by Chemical, 1945–56

TABLE 7

Chemical Used in Communities With Fluoridated Water, by Population Segment, Dec. 31, 1956 *

Population Segment	Number of Water Supply Systems	Chemical Used						
		Sodium Fluoride		Sodium Silicofluoride		Fluosilicic Acid	Ammonium Fluosilicate	Other and Not Specified
		Dry Feed	Soln. Feed	Dry Feed	Soln. Feed			
1,000,000 and over	5			2		3		
500,000–999,999	7			6		1		
250,000–499,999	12	2		10				
100,000–249,999	28	6	1	17		3		1
50,000– 99,999	31	4		23		4		
25,000– 49,999	60	13	1	39	2	1	1	3
10,000– 24,999	159	19	15	105	4	6		10
5,000– 9,999	131	25	21	71	1	10		3
2,500– 4,999	140	14	33	63	2	12	4	12
1,000– 2,499	133	9	67	31	3	19		4
Under 1,000	51	1	43	2	1	4		
Not specified	2	1						
Totals	759	94	181	369	14	63	5	33

* Revised data furnished by US Public Health Service.

Acknowledgment

The committee is greatly indebted to Franz J. Maier, Sanitary Engineer Director, US Public Health Service, for providing the statistical data appearing in the foregoing tables and figures.

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1. Maier, F. J. & Bellack, E. Fluorspar for Fluoridation. *Jour. AWWA,* **49**:34 (Jan. 1957).
2. Task Group Report. Status of Fluoridation in the United States and Canada, 1956. *Jour. AWWA,* **49**:41 (Jan. 1957).
3. Task Group Report. Study of Permanent Color Comparators for Fluorides. *Jour. AWWA,* **49**:417 (Apr. 1957).

Direct Spectrophotometric Determination of Chloride Ion in Water

Philip W. West and Hans Coll

A contribution to the Journal by Philip W. West, Boyd Professor of Chemistry, and Hans Coll, Research Asst., both of the College of Chemistry and Physics, Louisiana State University, Baton Rouge, La.

CHLORIDE ion is known to form stable complexes with ferric iron. The yellow color these complexes exhibit in acidic solutions is due to absorption bands in the near ultraviolet extending into the visible region. The maximum wave length of one of the prominent bands lies around 350 mμ, which makes it readily usable for spectrophotometric analysis. The intensity of this band may be considerably enhanced by the addition of perchloric acid.

Based on the above observations, a spectrophotometric procedure for the determination of chloride ion at concentrations as low as a few milligrams per liter has recently been proposed by the authors (*1*). The reagent employed is a solution of 0.014*M* ferric perchlorate in 12*N* perchloric acid. The volume of the unknown need not exceed 2.5 ml, and interferences from other ions are generally slight or nonexistent. The method can be considered as reliable, very simple, and particularly suitable for routine analysis of water.

Up to the present time three titrimetric procedures for the determination of chloride in water have been recommended as standard methods, namely the Mohr and Volhard titrations with silver nitrate, and a mercurimetric determination (*2*). The purpose of this study is to illustrate some of the possible advantages of the spectrophotometric procedure over the existing standard methods and to compare their performances in water analysis. Only the Mohr and the mercuric nitrate procedures were included in these comparative studies, because the Volhard method is more complicated, less accurate, and less applicable for low concentration ranges of chloride ion.

Standard Procedures

Reagents and procedure for the Mohr method were as specified in *Standard Methods* (*2*), except that, in order to facilitate the observation of the endpoints, a yellow light source was used for illuminating the titration vessel.

In using the mercuric nitrate method, the reagents were specified and the titrations were performed essentially according to the procedure outlined by *Standard Methods* (*2*). It was found, however, that the endpoint of the titration could be established more accurately through use of four blanks which contained the indicator and 0.05, 0.10, 0.15, and 0.25 ml respectively of mercuric nitrate standard solution. These blanks served as color standards for establishing endpoints after difficulty was encountered with attempts to titrate to one specific color because of the slow rate with which the reaction proceeded towards the endpoint. It was found that 5–10 min may be re-

quired before the color intensity of the indicator reaches its maximum. The titration was performed at a moderate rate until the first tinge of purple appeared. The sample was set aside, and after 15 min it was compared with the set of color standards. The excess volume of titrant was subtracted from the buret readings. The color standards were stabilized by the addition of gum arabic.

Spectrophotometric Method

Apparatus: Two spectrophotometers * were used, one of them in order to prove its satisfactory performance at 353 mμ. A tungsten lamp was used as the light source. Matched 1-cm glass cells † were also utilized.

Reagent: Shake 20–30 g of reagent grade Fe^{+++} perchlorate with small portions of 70 per cent perchloric acid in a glass-stoppered flask. Decant the acid and repeat this operation until the acid layer no longer appears yellow. Mount a coarse fritted-glass crucible of known weight on a suction flask, and transfer the purified iron perchlorate to the crucible. Press the crystals down with a glass rod flattened on one end, and remove the perchloric acid by suction. Reweigh the crucible filled with iron perchlorate on a triple beam balance, and remove iron perchlorate from the crucible until approximately 8 g are left. Dissolve this quantity in a few milliliters of distilled water, and add 1 liter of 70 per cent perchloric acid. The resulting solution then contains about 0.014*M* of iron perchlorate in 12*N* perchloric acid. The formula weight of iron perchlorate cannot be taken as a basis for calculating the exact strength of the solution with respect to iron, because part of the weight of the salt is due to adsorbed perchloric acid. The reagent is best stored in a closed system 10-ml buret ‡ which is equipped with a magnesium perchlorate charged drying tube at the inlet.

Procedure: Deliver 7.4 ml of reagent into a 10-ml volumetric flask which is protected from light by a black coating almost up to the mark. Transfer 2½ ml (or a smaller aliquot) of the unknown solution, containing not more than 50 mg/l of chloride, to the flask and bring the solution to volume with distilled water. Shake the flask to mix the solution and set it aside for a few minutes to cool. For accurate work cover the flask with a small bag of opaque paper so that the solution is completely protected from light. Measure the absorbancy of the solution at 353 mμ with respect to a blank containing only reagent and distilled water. Read the concentration of chloride from a calibration curve derived by using the same procedure with known amounts (10–100 mg) of chloride. A new calibration curve should be established every time a fresh reagent is prepared. A sample which contains 10 mg/l of chloride, under these conditions outlined above, should give an absorbancy reading of about 0.200, if 1-cm cells are used.

Remarks: The spectrophotometric readings obtained for a given concentration of chloride ion will, to a certain extent, depend on the concentration of the reagent with respect to Fe^{+++} as well as on the concentration of per-

* The spectrophotometers used were Models DU and B, both products of Beckman Instruments, Inc., South Pasadena, Calif.

† "Corvex" cells, made by Beckman Instruments, Inc.

‡ A 10-ml Machlett buret, container capacity 1 liter (Machlett & Son, New York, N.Y.).

chloric acid. By preparing a reagent solution of approximate strength and checking the reagent against standard chloride, setting up a calibration curve for each freshly prepared reagent, accurate results can be obtained consistently. The reagent is quite hygroscopic, and must be stored in a container (buret with reservoir) which is protected from moisture, so that changes of concentration can be avoided. The reagent should not be in contact with any organic material. A film of the reagent has to serve as the stopcock lubricant of the buret, because stopcock greases lose their lubricating properties when in prolonged contact with strong perchloric acid.

The treatment of iron perchlorate with perchloric acid removes undesirable traces of chloride ion which may be present in the salt. The absorbancy of a blank (7.4 ml of reagent diluted to 10 ml with distilled water) should not exceed 0.06 absorbancy unit with respect to distilled water (1 cm cells, 353 mμ).

Once chloride ion has been added to the reagent, the solution has to be protected against bright light to avoid decomposition of the complex and resulting marked decrease in absorbancy. Samples protected against light in a manner as described above give constant readings over a period of days.

A suspension of aluminum hydroxide can be used for clarification of turbid water samples: 125 g of potassium alum are dissolved in distilled water and precipitated by addition of excess ammonium hydroxide; the precipitate should be made free of chloride by repeated washing with distilled water, and the final volume made up to 500 ml.

TABLE 1

Summary of 25 Runs on Chloride Solutions *

Method	Sample Size *ml*	Average Reading	Chloride Ion—*mg/l*			Mean Deviation From Average *per cent*
			Average	Low	High	
Mohr	100	3.08†	13.04	12.7	13.5	±1.1
Mercuric nitrate	100	2.73†	12.13	11.8	12.5	±1.4
Spectrophotometric	2	0.198‡	12.45	12.1	12.9	±1.2

* Solutions contained 12.5 mg/l chloride.
† Milliliters buret reading.
‡ Absorbency units after subtraction of blank value.

Results of Experiments

A solution which contained 12.5 mg/l of chloride in distilled water was analyzed in 25 runs under identical conditions by each of the three methods in accordance with the procedures given above. The purpose was to obtain information as to accuracy and precision of the methods at low concentrations of chloride under conditions favorable for reproducing the results. Silver nitrate as well as mercuric nitrate titrants were standardized in ten runs each against a solution containing 2.00

mg of chloride ion in 100 ml. Because of the small volumes of titrant consumed at these chloride levels a buret with 50 scale divisions per milliliter was used. The runs were extended over several days. A calibration curve for the spectrophotometric method was established from ten points covering a concentration range from 0.0075 to 0.100 mg of chloride ion per 10 ml. The absorbancies were measured by means of a spectrophotometer (slit setting 0.55 mm). The test runs were performed in groups of five. Distilled water was taken as the reference for the spectrophotometer readings, and an average of five readings on blanks with respect to distilled water was subtracted. This somewhat unconventional procedure was justifiable from a statistical standpoint, because a variation in one blank value would accordingly influence a whole set of measurements. A summary of results is presented in Table 1.

TABLE 2

*Effect of Treatment With Aluminum Hydroxide Suspension on Absorbency of Water Sample**

Untreated Sample	Treated Sample
0.091	0.013
0.026	0.012
0.044	0.020
0.119	0.031
0.098	0.028
0.103	0.029
0.075	0.026
0.086	0.030
0.120	0.031
0.166	0.029

* Absorbency at 353 mμ with respect to distilled water.

Natural waters of various chloride concentrations were then used for comparative quantitative studies. Suspended material, if present, was first removed by filtration through coarse filter paper. In some cases the filtrate was still turbid and slightly colored, and further clarification by means of chloride-free aluminum hydroxide was employed prior to the spectrophotometric determinations. Exactly 7 ml of water sample was transferred to a dry test tube and 0.5 ml aluminum hydroxide suspension added. The solution was stirred and centrifuged until all aluminum hydroxide had settled to the bottom of the test tube. An aliquot not exceeding 2.5 ml was then taken for the determination of chloride and the final result multiplied by the factor 7.5/7.0, the volume occupied by solid aluminum hydroxide being neglected. Table 2 shows some typical results obtained by this treatment. The lowering of the absorbancies in those cases listed in Table 2 must be considered as sufficient, because the spectrophotometric procedure involved further dilution, at least by a factor of 4. By tests on solutions of known chloride content it was ascertained that treatment with aluminum hydroxide in the manner described did not cause any noticeable changes in the chloride concentration due to adsorption. Eight samples of natural waters were subjected to analysis by the three methods. Table 3 presents the results as obtained.

Finally, known amounts of chloride were added to two samples of natural waters whose chloride content had been determined previously (Samples 1 and 5 in Table 3). The chloride concentrations of the resulting solutions were calculated on the basis of the value determined by the spectrophotometric method (Table 4). In the solutions derived from Sample 5, clarification with aluminum hydroxide was necessary. Accuracy and precision of the results in Table 4 are only meaningful

in case of the spectrophotometric procedure (Method C); the titrimetric procedures (Methods A and B) were only included as a check, and the results of these methods cannot be attributed the same weight as in the spectrophotometric procedure, because of the small number of runs or small sample sizes which lead to a more extensive error.

Conclusions

Several factors have to be considered in any attempt to interpret the results of this work with respect to precision and accuracy of the methods applied. The precision achieved in titrimetric analysis will to a certain extent depend on the skill of the experimenter, while in spectrophotometric work the results

TABLE 3

Determination of Chloride Ion in Natural Waters

Sample No.	Method*	Sample Size *ml*	Chloride—*mg/l*			Mean Deviation From Average *per cent*
			Average†	Low	High	
1	A	100	4.95 (10)	3.8	5.5	±7.7
	B	100	3.9 (10)	3.7	4.4	±2.5
	C	2	4.15 (10)	3.9	4.5	±3.0
2	A	100	4.8 (3)			
	B	100	3.5 (3)			
	C‡	2	4.7 (8)	4.4	4.9	±3.0
3	A	100	11.6 (3)			
	B	100	10.2 (3)			
	C‡	2	11.4 (8)	11.3	11.5	±0.6
4	A	100	19.8 (3)			
	B	100	18.2 (3)			
	C‡	2	19.0 (8)	18.6	19.4	±1.0
5	A	100	22.9 (8)	22.5	23.2	±0.8
	B	100	21.8 (10)	21.3	22.1	±1.1
	C	2	22.2 (10)	21.8	22.8	±1.0
6	A	50	128.8 (3)			
	B	50	128.0 (3)			
	C‡	0.5§	125 (8)	124	127	±0.8
7	A	10	610 (3)			
	B	10	636 (3)			
	C	0.1‖	591 (8)	585	596	±0.6
8	A	5	1,201 (3)			
	B	6	1,200 (3)			
	C	0.06#	1,180 (8)	1,170	1,189	±0.5

* Letters refer to following methods: *A*, Mohr; *B*, mercuric nitrate; and *C*, spectrophometric.
† Number in parentheses indicates number of runs for each sample.
‡ Sample was treated with aluminum hydroxide.
§ 1 ml, diluted 1 to 2.
‖ 1 ml, diluted 1 to 10.
1 ml, diluted 1 to 16.7.

can be assumed as essentially unaffected by human factors; here the quality of the instrument is decisive for the precision of the measurements. With reference to the foregoing experiments it appears that the precision expressed as percentage of deviation from the average is of comparable magnitude for all three methods. As to the titrations, it can be expected that the detection of the endpoints in a series of runs under identical conditions will give rise to small deviations only. The results derived from the spectrophotometric measurements may be considered as typical with respect to precision. Temperature changes may be one controllable source of error. It was found that the temperature effect is inappreciable (*1*), and no corrections were applied. The percentage of error due to volumetric measurements (transfer of sample) will be higher in the spectrophotometric procedure, but even in this case it should not be appreciable.

TABLE 4

Determination of Chloride Ion in Selected Samples

Samples*	Theoretical Chloride Ion Concentration *mg/l*	Method†	Average Determined Chloride Ion Concentration *mg/l*‡	Mean Deviation From Average *per cent*	Error With Respect to Theoretical Value *per cent*
1 a	24.05	A B C	24.5 (2) 22.9 (2) 23.8 (8)	±1.0	−1.0
1 b	44.0	A B C	43.6 (2) 44.0 (2) 43.2 (8)	±0.3	−1.8
1 c	103.7	A B C	104.3 (3) 103 (9) 102.5 (8)	±0.6	−1.2
5 a	32.0	A B C§	32.4 (2) 31.6 (2) 31.8 (8)	±0.1	−0.6
5 b	41.8	A B C§	41.5 (2) 42.5 (2) 41.5 (8)	±0.7	−0.7
5 c	71.05	A B C§	72.5 (3) 71.0 (6) 70.6 (8)	±0.4	−0.6

* Samples No. 1 and 5 from Table 3.
‡ Parentheses indicate number of runs for each sample.
† Letters refer to: *A*, Mohr; *B*, mercuric nitrate; and *C*, spectrophotometric methods.
§ Sample was treated with aluminum hydroxide.

For low concentrations of chloride the precision of the Mohr titration has been estimated to be ± 0.1 mg of chloride ion, corresponding to 0.2 ml of titrant, and the precision of the mercuric nitrate method is given as ± 0.05 mg, corresponding to 0.1 ml of titrant (*2*). These values have been considered to be constant over a range of

chloride concentrations. In spectrophotometric work it may be assumed that instruments such as the ones used will give readings reproducible within 1 per cent transmittance or less, irrespective of dial reading. Based on these values, Fig. 1 illustrates the variation of percentage of error with concentration of chloride present in the unknown. The applicable experimental conditions were those outlined above (100-ml samples for the volumetric procedures, 2.5-ml samples in a total of 10 ml for the spectrophotometric procedure). Figure 1 indicates that at low chloride concentrations a higher precision, expressed in terms of percentage of error, can be expected from the spectrophotometric method. In the experimental studies on this method it was found that deviations from the average in individual measurements were well within the range defined by Curve *C*. It can be implied that the proposed spectrophotometric method is free from uncontrollable effects which may cause appreciable random deviations. The readings were reproducible within less than 1 per cent transmittance. The resulting percentage of error reaches a minimum at 0.434 absorbancy unit (*3*) which in this case corresponds to about 21 mg/l of chloride ion. At higher concentrations appropriate dilutions can be applied to obtain readings in the order of 0.434 absorbancy unit. According to Fig. 1 at 17 mg/l chloride the percentage of error should be the same for Procedures *B* and *C* (about 3 per cent). Expressed in absolute amounts of chloride this uncertainty equals 50 mg for Procedure *B*, but only 1.2 mg for Procedure *C*.

An unambiguous evaluation of accuracy on the basis of this work does not seem to be possible. It appears from Tables 1, 3, and 4 that at low chloride levels the Mohr method tends to give high results, if the titrant had been standardized against solutions of higher chloride content. This is consistent with the observation that the endpoints become more distinct once an appreciable precipitate of silver chloride has formed. The reverse seems to hold for the mercurimetric method. At low chloride concentrations the results tend

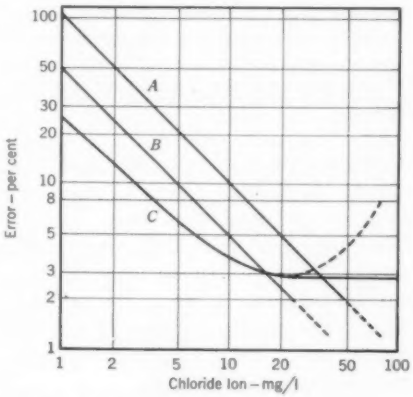

Fig. 1. Percentage of Error Against Chloride Concentration

Methods are represented by the following curves: A, *Mohr;* B, *mercuric nitrate; and* C, *spectrophotometric methods. The dashed line extending from Curve* C *indicates the increase in percentage of error for unknowns containing more than 21 ppm of chloride if they are not diluted.*

to be too low. This effect may be explained by the law of mass action governing the dissociation of the mercuric chloride. At low chloride concentrations the values found increased in the order of the procedures: mercuric nitrate, spectrophotometric, Mohr. Standardization of the titrants against varying amounts of chloride, comparable to a calibration curve, should lead to higher accuracies. In spectrophotometric work the accuracy will primarily

TABLE 5

Interfering Ions on Chloride Concentrations *

Ion	Interfering Ion* mg/l	Extent of Interference
Sulfate	120	slight (+)
Nitrate	>1,000	negligible (+)
Bromide	7	moderate (+)
Iodide	—	slight; precipitates above 800 mg/l
Phosphate	3,000	negligible (−)
Fluoride	1,500	negligible (−)
Mercury (Hg^{++})	—	heavy, must be absent (−)

* Amount in mg/l of ion giving a deviation of about 3 percent in a chloride concentration of 20 mg/l per unknown.

depend on the quality of the calibration curve. In Tables 3 and 4, where the chloride concentrations were obtained from the same calibration curve, the results all seem to be slightly low. Special care was taken in the preparation of the standard curve for the statistical runs (Table 1); there the accuracy was practically ideal.

It is to be expected that the spectrophotometric method will be more sensitive toward colored contaminants present in natural waters. Treatment with aluminum hydroxide can be considered as adequate to eliminate such interferences in most cases. Occasionally, decolorization with permanganate and oxalate ion may be required. A large excess of oxalate ion must be avoided.

Table 5 enumerates interference effects of other ions. A more complete discussion, including the determination of chloride in the presence of bromide has been given elsewhere (*1*). Sulfate ion, if present at a concentration greater in weight than six times that of chloride, will exert a noticeable influence. Thus, among common constituents of natural waters, sulfate is probably the only potentially interfering ion. The unknown should not contain a large excess of Fe^{+++}, acids, or alkali. Potassium ion forms an insoluble perchlorate and interferes by precipitation if present in concentrations above 300 mg/l.

It is felt that only in a few exceptional cases will interference from other ions render the spectrophotometric method inapplicable for the determination of chloride in water. With respect to reliability, precision, and accuracy the proposed procedure compares advantageously with the standard titrimetric methods. Only a small volume of sample is required, and the operations involved are very simple. Chlorides can be determined in the presences of iodides and bromides.

Acknowledgment

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Strontium Content of Wisconsin Municipal Waters

M. Starr Nichols and Dorothy R. McNall

A contribution to the Journal by M. Starr Nichols, Asst. Director, and Dorothy R. McNall, Chemist, both of the State Lab. of Hygiene, Univ. of Wisconsin, Madison, Wis.

IN 1932, Collins, Lamar, and Lohr (*1*) reported strontium to be present in water of three separate wells from the city water supply of Waukesha, Wis., in amounts of 20, 13 and 2 ppm, respectively. Again in 1952 samples from this city were tested for strontium by the USGS laboratory at Columbus, Ohio, under the direction of W. L. Lamar, district chemist (*2*). The results on three separate wells showed strontium contents of 52, 33, and 40 ppm.

The Oak Ridge National Laboratory, Oak Ridge, Tenn. (*3*), in 1952 made determinations of strontium on water, sewage influent, and effluent samples from Waukesha, with the following results: 29.0 and 25.0 ppm strontium from two well samples; 17.8 ppm strontium from each of two samples of sewage influent; and 16.0 ppm strontium from each of two samples of sewage effluent.

The results reported by Collins, Lamar, and Lohr (*1*) and Lohr and Love (*2*) were obtained by spectrometric methods. These reports caused the Wisconsin State Laboratory of Hygiene to make a survey of municipal waters from various localities in Wisconsin.

Review of Research

In 1935 Braidech and Emery (*4*) made use of the spectrographic method for the determination of various metals present in some 24 municipal waters of the United States. They considered their data semiquantitative, and reported strontium present in amounts varying from 0.1 ppm in waters from Santa Fe, N.M., to 10 ppm each in municipal waters from Bismarck, N.D., and Jacksonville, Fla., with most of the results less than 5.0 ppm. Alexander, Nusbaum, and MacDonald (*5*) made spectrographic analysis of waters from some 52 municipalities and reported strontium to be present in amounts varying from 0.0058 ppm for Charleston, S.C., to 1.9 ppm for the raw ground water from Wichita, Kan. Their three results for Santa Fe were 0.14, 0.13, and 0.033 ppm, respectively. These authors produced excitation of the metal by means of a modified "copper spark" method using a high voltage spark between copper electrodes upon which the sample, one drop to each electrode, was placed and dried over P_2O_5. In 1950 West, Folse, and Montgomery (*6*) made flame spectrometric determinations of sodium, potassium, and calcium in natural waters, and showed how radiation buffers could be used to facilitate the measurement of these cations. No tests for strontium were included in their report. In 1955 Chow and Thompson (*7*) determined the strontium content of sea water using the flame spectrophotometer, and

TABLE 1

Transmission Readings for Strontium Values in Buffered Solutions of Various Strengths

Strontium Content *ppm*	Transmission Readings		
	Full Strength	Half Strength	Quarter Strength
4.0	90.0	90.0	90.0
3.0	78.8	77.0	77.1
2.0	66.0	64.8	63.8
1.0	53.7	52.5	50.8
0	41.8	39.5	38.0

gave radiation interference values for the various other ions encountered. They used a synthetic sea water of varying chlorinity range to prepare their strontium standards.

Results of Experiments

In Wisconsin laboratory experiments the intensity of radiations emitted by strontium, when water was fed to flame with special atomizer burner, was measured with a spectrophotometer fitted with a flame attachment, a hydrogen-oxygen burner and a phototube multiplier.* The strontium spectral line of 460.7 mμ was selected as the most suitable, because of the purity and intensity of the radiation. Other values on the instrument were: a slit width of 0.2 mm; selector switch set at 0.1; oxygen pressure of 8 psi; hydrogen pressure of 9 psi; zero suppression at 1.0; and full sensitivity. The sensitivity control was adjusted so that the transmission dial would read 90 when the 4.0-ppm strontium standard was fed to the flame, and the 0.0-strontium standard using various radiation buffers would read in the vicinity of 41.0 when the 4.0-ppm strontium standard read 90 on the transmission dial.

For extreme accuracy it appeared necessary to prepare standard radiation buffers containing in solution the ions present in each natural water in the same concentration, and to use this synthetic water to prepare a standard curve for each natural water as the mineral analysis of each municipal water was available. After further work it was decided to use approximations of these concentrations of natural solutes. The full-strength radiation buffer used contained: 68.1 ppm Ca ion (as chloride); 36.0 ppm Mg ion (as sulfate); and 4.6 ppm Na ion (as chloride). These amounts were used because they represented the average cation content of Madison city water, which corresponds in ion content quite well with many hard waters of the state. This buffer was diluted with distilled water to make half-strength and quarter-strength radiation buffers. These three radiation buffers were used to make standard strontium curves, from which to measure the strontium contents of waters corresponding approximately with the solids content of these buffers. The transmission values of these standards made with these radiation buffers are given in Table 1.

* The spectrophotometer used was a Beckman Model DU, product of Beckman Instruments, Inc., South Pasadena, Calif. The flame attachment was Model No. 9220, the hydrogen-oxygen burner, No. 4020; and the phototube multiplier, No. 4300.

TABLE 2

Transmission Equivalent Values of Various Ions and Compounds

Ion or Compound (1.0 ppm)	Equivalent Value *ppm Sr*
Calcium	0.0057
Magnesium	0.0005
Potassium	less than 0.0001
Sodium	0.013
Chloride	less than 0.0001
Sulfate	0.0001
Sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$)	0.0021

Radiation interference of the various constituents encountered in Wisconsin waters were measured for their transmittance value under the same conditions as those used for the strontium standards. By using a range of concentrations for each ion similar to the variance encountered in these natural waters but dissolved in distilled water, it was possible to set up strontium

TABLE 3

*Strontium Values in Wisconsin Communities**

Community	Strontium Content *ppm*	Community	Strontium Content *ppm*	Community	Strontium Content *ppm*
Algoma		Greendale	32.8	Pewaukee	
Well No. 1	1.32	Hartford	2.46	Well No. 2	6.68
Well No. 2	1.40	Horicon	3.56	Preble	
Allouez		Hustisford	2.24	Well No. 1	6.60
Well No. 1	9.50	Iron Ridge	5.90	Well No. 2	13.0
Well No. 2	5.20	Johnson Creek	1.70	Random Lake	5.00
Webster Ave.	6.60	Juneau	3.98	Reeseville	1.30
Green Ave.	9.00	Kaukauna		Saukville	1.18
Beaver Dam	1.46	Well No. 4	29.0	Sturgeon Bay	
Brandon	2.33	Well No. 5	25.4	Well No. 1	1.28
Brown Deer	22.6	Well No. 6	33.6	Well No. 5	2.54
Burlington		Well No. 7	29.6	Sturtevant	12.8
Well No. 6	1.80	Kewaskum	14.4	Union Grove	
Campbellsport	39.1	Kewaunee		Well No. 1	14.0
Cedarburg	6.8	Well No. 1	2.13	Well No. 2	12.6
Cedar Grove	7.6	Well No. 2	1.10	Walworth	
Clyman	1.2	Kimberly	8.80	Well No. 1	1.92
De Pere		Kohler		Watertown	
Front St.	14.7	Well No. 2	6.80	Well No. 1	1.12
Main Ave.	29.0	Well No. 3	4.00	Well No. 3	1.10
Fond du Lac		Well No. 4	1.54	Well No. 4	1.06
Well No. 10	1.55	Little Chute	7.00	Waukesha	
Well No. 11	12.60	Lomira		North St.	38.4
Well No. 12	10.60	Well No. 1	14.2	Newhall Ave.	32.3
Well No. 13	10.60	Well No. 2	14.6	Moreland Ave.	25.6
Well No. 14	2.76	Luxemburg	1.00	Baxter St.	12.8
Well No. 15	10.00	Mayville	3.30	Waupun	
Fox River Heights,		Menomonee Falls	34.5	Well No. 2	2.25
S. D.	4.80	Mukwonago		Well No. 9	1.96
Fredonia	3.64	Well No. 1	2.10	Wauwatosa	
Glendale	8.80	Well No. 2	2.30	Well No. 4	27.6
Grafton	1.14	New Holstein	1.16	Well No. 5	27.8
Green Bay		N. Fond du Lac	9.80	Well No. 6	28.4
Cass St.	6.40	Oakfield	3.50	Well No. 7	33.0
9th St.	3.30	Oconto	1.90	Well No. 8	31.0
Roland Rd.	3.00	Oostburg	12.2	Well No. 9	37.4
Military Ave.	3.40	Peshtigo		Well No. 11	2.86
Shawano Ave.	3.20	Well No. 3	1.90	Williams Bay	1.04
Highland Ave.	4.00	Well No. 4	1.90	Winneconne	3.15
Mason St.	5.20	Pewaukee		Wrightstown	17.5
Gray St.	3.40	Well No. 1	13.40		
James Church	3.40				

* Communities with content over 1.0 ppm.

values of these ions and compounds, with a wavelength of 460.7 mμ and a slit width of 0.2 mm. These values are shown in Table 2. These equivalent values were used to correct the strontium value obtained on a small number of water samples which, by mineral analysis, were shown to vary somewhat widely from the synthetic radiation buffers.

In Table 3 are shown the values found in 100 separate municipal waters

Fig. 1. Strontium Values in Wisconsin Communities

It can be seen that the communities with over 1.0 ppm strontium in their waters (represented by circles and squares) are concentrated in the eastern section of the state.

in Wisconsin. These values range from 39.1 ppm, found at Campbellsport, down to 1.0 ppm, found at Luxemburg. There are 279 waters not shown in Table 3 which have a strontium content below 1.0 ppm. In chemical analyses the strontium is included in the calcium value, and if the oxalate precipitation followed by the permanganate titration method is used, any strontium present will not disturb the ion balance. This partially explains why some of these high values were not found previously. The accompanying map of the state, Fig. 1, shows the high values for strontium to be found in waters from the eastern part, extending from the Illinois border to the northeastern boundary with Michigan. In all other parts of the state the strontium content, according to present data, is less than 1.0 ppm.

Radioactivity

In its natural state, strontium (atomic weight 87.63, atomic number 38) is not considered to be radioactive; this element is not to be confused with strontium 90 of the same atomic number, although its chemical reaction is similar. Although no radioactivity was expected from the solids of waters found high in strontium, nevertheless, one of the water samples from Waukesha (38.4 ppm strontium) was evaporated. The residue was subjected to the alpha-beta-gamma proportional counter.* Background radiation and a similar residue from Madison city water, low in strontium, were likewise subjected to a total count in the same counter. The results showed background radiation of 30 cpm, radiation in Waukesha water of 30 cpm, and in Madison water of 28 cpm. The laboratory is not equipped with coincidental counting equipment for measuring very low radioactivity, but the values given show there is no significant radioactivity in this water containing large amounts of strontium.

* Serial No. 69, product of the Nuclear Measurements Corp., Indianapolis, Ind.

Geological Relationship

Because of variations in formations penetrated in drilling the various wells and lack of information on formations cased off, it is not known which formation is yielding the high-strontium waters. In this eastern part of Wisconsin there are geologic faults extending in a north and south direction, and they may have some bearing on the character of these waters. Similar geologic formations are found in the southwestern area of the state, but no waters in that area have been encountered to date which yield high strontium values.

Summary

Analyses of some 380 municipal waters from Wisconsin showed a strontium content ranging from less than 0.1 ppm to a high value of 39.1 ppm. The high-strontium values were found in waters along the eastern part of the state.

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R703	PANEL DISCUSSION	Plastic Pipe	Apr 57	11	25¢
R704	STAFF REPORT	1955 Operating Data Survey	May 57	144	75¢
R705	WOLMAN	Radioactive-Waste Disposal	May 57	7	20¢
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R709	PANEL DISCUSSION	Cleaning Small Mains	Aug 57	14	25¢

Design of Underground Storage Reservoirs

Allan B. Patterson

A paper presented on June 19, 1957, at the Canadian Section Meeting, Winnipeg, Man., by Allan B. Patterson, Deputy Comr. of Works, Water Works Div., Municipality of Metropolitan Toronto, Ont.

MUCH has been written in the JOURNAL (*1–3*) on the methods and techniques of sizing storage reservoirs, which fall roughly into four classifications: [1] overhead standpipes or tanks; [2] impounded storage reservoirs; [3] filtered-water clear wells, associated with pumping and filtration plants; and [4] underground distribution storage reservoirs. This article will deal with some important aspects of the underground distribution storage type of structure.

Reservoirs of this type in municipal water works systems play an important part in the economical supply of water. Their value in promoting continuity of normal service during periods of unusual demand cannot be overemphasized and probably represents the greatest single benefit. Metropolitan Toronto is witnessing the most amazing suburban growth in its history. As pointed out in an address by the chairman of the metropolitan council:

> Perhaps the best illustration of the economic change which has been going on is the one that is closest to us and with which we are most familiar. In 1945 suburbanization started with a vengeance; the population grew by leaps and bounds; it soon filled the city and spilled over the borders. The city's population remained static at just under 700,000, but the population in the suburbs grew from less than 100,000 in 1945 to over 700,000 in 1956. That is seven times in 11 years.
>
> Since 1945 we have seen the demonstration of a most amazing new mathematical proposition, that you can have multiplication by subdivision. We have seen the miracle of suburbia. All of a sudden everybody wanted to get out into the country so that their children would have freedom from sidewalks and pavements [and] so that they could enjoy the fields and the streams, but it was not long before they discovered that cars operate better on pavements than in mud holes [and] that it is better to have water in the tap than in the cellar. Thousands never knew before what a sump pump was. Now it is standard equipment. . . .
>
> The larger suburban lawn and garden plot is, no doubt, a permanent fixture, requiring new thinking with respect to the magnitude of water storage reservoirs; to assist those contemplating future construction, some important aspects of these reservoirs are presented in this article.

Gatehouse Design

One of the most interesting features to be found in connection with underground storage reservoirs is the valve or gatehouse design. The reservoir supply line should contain a control gate valve reasonably close to the reservoir proper, and, if associated with a pumping station for repumpage of the stored water, it should be adjacent thereto. This valve should be equipped with a bypass of the double-valve type

to facilitate the dewatering of the supply main on either side or section of the main. The methods illustrated in Fig. 1 and 2 makes use of two bypass valves installed adjacent to the bypass pads on the main valve body and a special return bend elbow. Both ends of the valve and the elbow are arranged for mechanical couplings to speed installation and to facilitate removal. With such an arrangement, applicable on all large trunk distribution valves in the Toronto area in the 30-in. size and above, dewatering of the main is quickly accomplished. Inside the gatehouse the reservoir supply main is arranged to suit individual design requirements.

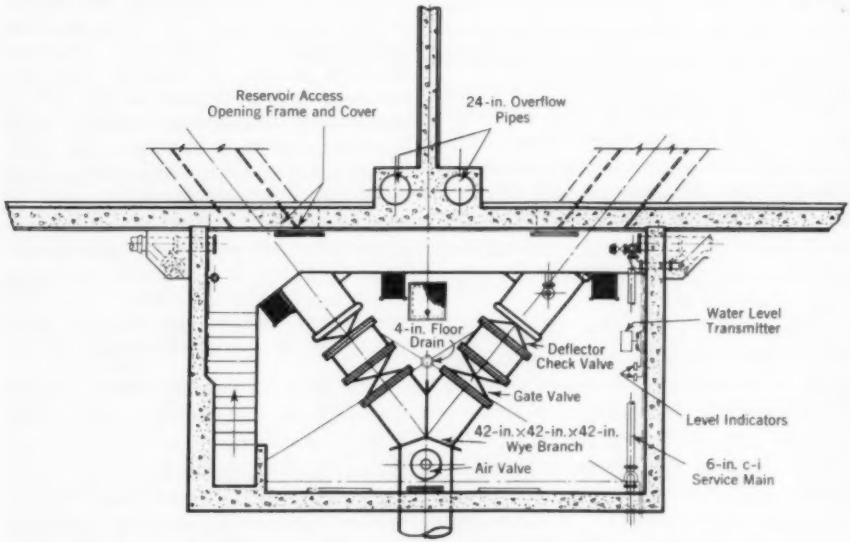

Fig. 1. Projected Gate House Structure, Utilizing Wye-Branch Pipe Entry

In the divided or two-basin reservoir, the type used in Toronto, the gatehouse is constructed at the extreme end of the dividing wall at its junction with the main reservoir wall, and is either set into the reservoir so that the outer wall is a clean unbroken line or is built adjacent to the main structure, using the main reservoir wall as one of the four sides. The choice is entirely at the utility's option, unless site limitations dictate, because the latter method obviously requires some 20 ft of additional space to permit the gatehouse to project beyond the main reservoir structure. This should not cause any concern, because in order to maintain a slope of at least 3:1 on the sloping banks of earth cover placed around a reservoir, and with the reservoir projecting ½ of its depth above the adjacent ground, it must be set at least 30 ft from the property line.

Figures 1 and 2 illustrate the two alternative methods of design usually employed in the design of gatehouse

structures. Figure 1 shows the projected type, which lends itself well to a wye-branch pipe entry. Although this permits a neat piping arrangement, a word of caution is necessary:

Toronto's experience with the wye-branch type of design in cast iron has not been ideal, because of failure, usually evident along the horizontal parting line of the casting and due to stress concentrations in the crotch of the wye casting. These troubles can probably be overcome with the use of fabricated-steel specials, suitably ribbed and protected against corrosion (*4*). If a casting is required, however, one of superior cast iron, ductile iron, or noduloy can be used, also suitably ribbed and designed with well rounded corners and with all thin or weak sections amply proportioned.

Figure 2 illustrates the indented method of design for the gatehouse, which lends itself more directly to a tee-inlet connection rather than a wye branch. It is not implied that one is superior to the other, all things being equal, but there are factors of site limitation, ground contours, and architectural appearance that will dictate the final choice.

Control Valves

Two reservoir control valves, or basin-isolating valves, should be incorporated in the design of the piping, and considerable latitude can be given here. The gate valve lends itself rather well to extension spindles, and if the operators are to be placed on the floor above, this arrangement is quite neat and tidy. Working pressures admittedly are not high, but serious consideration should be given to specifying a valve of at least 125-psi design pressure. This is because of the extra strength, ruggedness, and more trouble-free operation associated with the heavier design.

In larger reservoirs electric motor-operated mechanisms of the torque-

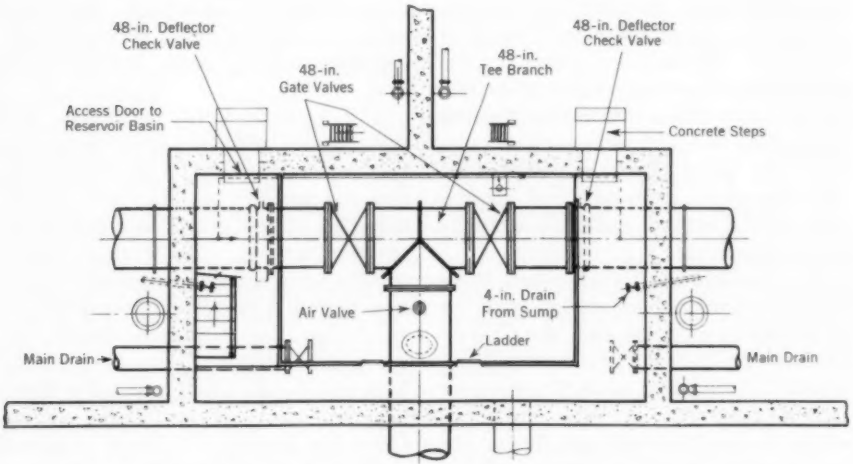

Fig. 2. Indented Gate House Structure, Utilizing Tee-Branch Pipe Entry

limiting type may be necessary, and it is more certain that routine operation and maintenance will be performed with motor operation, as opposed to the 10,000 or so manual turns required to operate a 42-in. geared, head-stock operated, gate valve from the fully open to the fully closed position.

It has been standard practice in Metropolitan Toronto to build large underground reservoirs in two basins. The division wall is so designed and constructed that either half of the reservoir may be completely dewatered for inspection while the other half remains in service. In addition to this most important function, by means of the installation of a bypass valve at the end of the wall remote from the inlet a most desirable and necessary circulation of water can be established whereby short circuiting and stagnation of the stored water is virtually impossible.

To complete the picture, then, there are two check valves, one in each leg of the tee or wye just after the division has been made in the gatehouse. Their function is such that when the reservoir is being filled, the inlet valve must open while the outlet closes, and during the period when reservoir water is being used, the reverse functions must be performed. The check valve should not be of the leak-tight design, because of the rather low unseating pressures and the ever present danger of sticking in the closed position.

Reservoir deflector valves have been designed for this purpose and are installed in pairs, one in each of the branches connecting the main supply line to each basin. Each valve consists of a rugged body casting through which a stout stem has been installed in a horizontal position. This stem is securely keyed to a butterfly type disc which closes against lugs on the body. Since these lugs are not continuous, as are the usual seats, the chance that the disc will remain in the closed position is extremely remote. In addition the horizontal stem is installed a few inches above the pipe centerline so that a slight differential on either side of the valve is sufficient to cause it to function. A positive handle and locking device is incorporated on the outboard end of the stem and a rugged, foolproof arrangement makes it possible to lock the valve in the open position. This arrangement is, of course, necessary when one basin is out of service requiring the remaining basin to float on the line.

The operation of inspection and maintenance with such an arrangement becomes relatively simple and means that the reservoir is never off the distribution system completely during inspection periods. The work necessary to fill a large reservoir after the inspection period is considerably reduced by employing the two-basin design, because it is necessary only to open the bypass valve to admit water for flushing purposes and for partial filling. Once the basins have been equalized and a sample cleared for sterilization, the half-full reservoir can be returned to service on a Friday night and filled over the weekend period, ready for normal service on Monday morning.

Other Design Features

Smaller, but nonetheless important, features in the piping design should also be stressed. All important connections to the reservoir, such as sample lines and reservoir level, float pressure connections, should be constructed of brass or copper pipe, of regular iron pipe size, to the first control or shutoff

valve, in order to minimize corrosion problems. They should be kept tight to the walls and away from areas where they can be kicked or accidentally broken by maintenance forces.

An automatic air valve should be installed at or near the high point of the supply pipe, which usually occurs near the entrance tee, to admit air if a water hammer condition should ever exist during a period when the reservoir has to be taken out of service. Under these conditions an air valve is the last fitting on a closed system, and if a sudden drawdown of district pressure should occur, the air valve will admit air and minimize the possibility of pipe collapse.

For example, during a routine fall inspection of the 50-mil gal St. Clair Reservoir, the check valve, or more properly in this case the flap valve, which normally closes when the reservoir is filling, was pinned open at the floor stand above, allowing the reservoir to fill because the other basin was empty for inspection purposes. Instructions had been left to raise the level in this basin by 4 ft on this particular night. The floor was at times a little in excess of this, and eddy currents and forces easily overcame the torsional resistance of the long operating spindle. The valve suddenly closed, with the result that the district suddenly became a closed system. Naturally, a serious water hammer condition existed, and had it not been for the design of the check or flap valve well, permitting it to act as a differential surge tank, and for the air valve opening on negative main pressure, serious damage would have resulted. An air valve is therefore important, and an inspection manhole, if possible, is also desirable, especially on steel or concrete pipelines.

Sites for large covered reservoirs are not easy to obtain in builtup areas, and yet the economics of the design usually dictates they be built close to the load center.

The help and cooperation of the parks and recreation officials are usually solicited, since the flat expanse of the covered reservoir roof affords ample scope for development once the construction forces have completed their work. The type and extent of park development that is to follow will dictate the type of roof loading that must be provided for, and from that point an economical design is decided upon.

Drainage System

An important feature of the covered reservoir is the method of roof and footing drainage. There are two systems in use in metropolitan Toronto, both of which have functioned well. Figure 3 illustrates the type employing granular material on the entire roof, which is constructed in the following fashion:

A 12-in. diameter concrete pipe as a reservoir footing drain is laid partly encased in concrete, the unencased part of the pipe having open joints. Coarse-graded gravel, approximately $\frac{3}{4}$ in. in diameter, of the type used for concrete masonry, is then placed around the footing drain for a distance of 2 ft from the outside diameter of the pipe bell. Clean sharp sand of the type used for concrete masonry is then placed to a depth of 9 in. on the side and top of the gravel, and pit run gravel is then carefully placed adjacent to the face of the reservoir walls for a distance of 6 in. and on the entire roof of the reservoir to a depth of 6 in.

Temporary sheeting is used at the edge of the graded gravel, sand, and pit

run gravel layers on the face of the wall, to avoid mixing and movement between general backfill and the sand and gravel. This material must, of course, be placed at the same rate as the general backfill and must be similarly compacted. Care must also be located at each corner to facilitate cleaning and to detect excessive dry-weather flow, which might indicate leakage.

Figure 4 illustrates the second method often used for roof drainage, employing a system of perforated

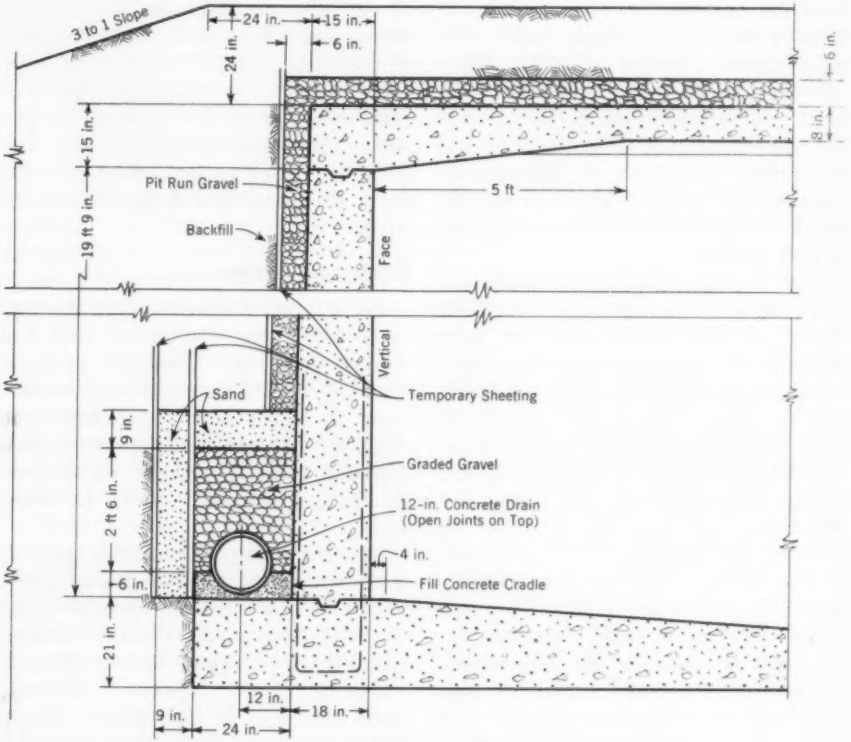

Fig. 3. Use of Granular Material in Reservoir Drainage

This cross-section side view of a typical covered reservoir illustrates the use of granular material in roof and footing drainage. Temporary sheeting is removed as materials are put in place.

taken that the junction between the graded gravel on the roof and that on the face of the wall is not broken and that full thickness is maintained. In order to intercept the flow of water from the footing drains, manholes are underdrainage pipes, laid in pattern, with down pipes and footing drains. The main system of roof drainage consists of 4 and 6-in. diameter perforated-fiber pipe, each pipe having two rows of ½-in. holes spaced 120 deg apart on

4-in. centers. The pipes are spaced at approximately 50-ft centers and drain to two main 6-in. lines similarly perforated. Each of these lines is carried over and down the vertical wall of the reservoir in cast-iron soil pipe and connected in turn to the main drain serving the structure proper. All perforated pipes on the reservoir roof are laid with $\frac{3}{4}$-in. graded gravel and coarse sand placed under, around, and over them for a total quantity of $1\frac{1}{4}$ cu ft of gravel per foot. These drains are not laid, of course, until the general backfilling and grading of the earth cover on the roof of the reservoir has been completed.

Similarly, the 6-in. footing drains of perforated-fiber pipe are laid in a bed of coarse gravel and sand, and extreme care is taken to minimize disturbance during backfilling operations.

Protection and Safety

The design of the gate or valve house can be very pleasing architecturally, and various treatments are used. Of paramount importance, however, is the incorporation of features designed to prolong the structure against not only the forces of nature, but also the even greater forces of vandalism from a 24-hr bombardment of sticks, stones, and other materials. Doors should be metal faced, and windows, if they must be installed, should be high, strong, and screened. Floodlights of the recessed type at the top corners of the gatehouse structure not only provide a dramatic effect, but also tend to dis-

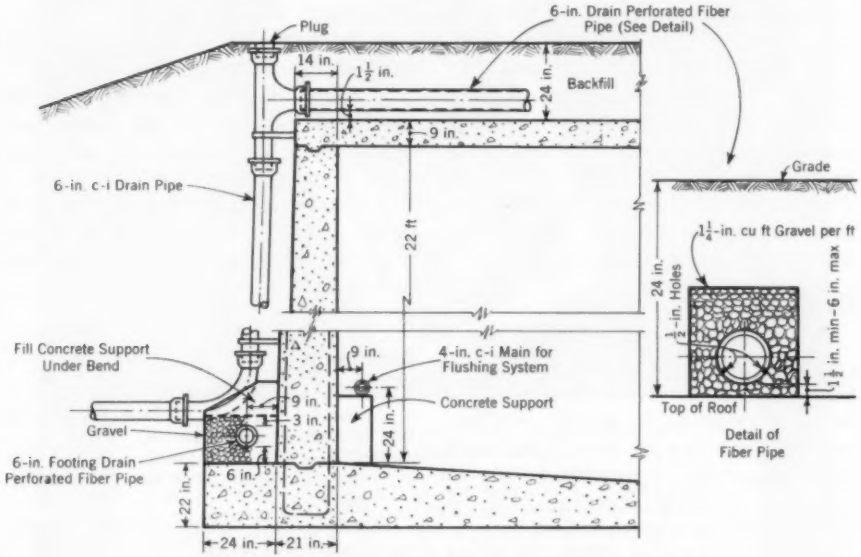

Fig. 4. Use of Perforated Pipes in Reservoir Drainage

This cross-section view shows how perforated underdrainage pipes may be used for reservoir roof and footing drainage. Three concrete supports (each 12 in. by 8 in.) are placed for every 16 ft of flushing main.

courage night loiterers and vandals.

Inside the gatehouse, a severe, corrosive atmosphere usually exists due to the presence of the large body of cold water. The cost and extent of the auxiliary services located therein are small, and an initial premium for waterproof wiring, lighting, and switching, a source of heat for a minimum of 55°F, and the selection of other incidental components to withstand this atmosphere is an extremely worthwhile investment.

Walkways and stairs are best constructed of reinforced concrete with some form of carborundum or antislip material in the treads. Ladders, railings, gratings, and metalwork of double-galvanized protection will also provide the maintenance forces with fewer problems of upkeep.

Civil Defense

The possibility exists that, under conditions such as the civil defense authorities mention from time to time in connection with atomic warfare, underground storage reservoirs could play an extremely important part in any plan to make water available in times of dire emergency. Certainly, in the event of a heavy fallout of radioactive material, it is likely that they would be the only large sources of safe water. To this end, and to facilitate the withdrawal of water by tank wagon or fire department pumper trucks, some form of underground service pipe should be laid from the reservoir terminating in a tee in a chamber near the curb or street. To each leg of the tee a short piece of pipe containing standard firehose isolation valves should be installed. As this line could represent a possible source of reservoir contamination, if left coupled to the reservoir drain, a short piece of pipe with ends arranged for mechanical or some other form of quick coupling could be left in the gatehouse ready for instant connection to the main reservoir drain valve when required. A second obvious feature is to have sufficient roof access manholes located as close to the reservoir walls as possible to permit pumping by truck should such an emergency occur.

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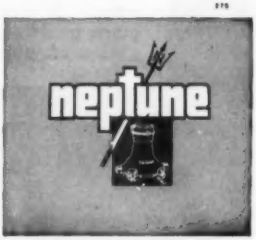

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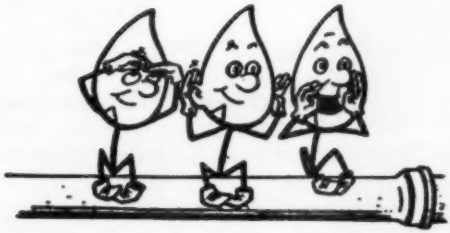

Percolation and Runoff

The Otomic Age is just around the corner for northern New Jersey—and we do mean *O*tomic for with almost everyone against anyone else's plan to develop the area's water resources and with a drought that has already drained existing reservoirs drier than they were in the critical days of 1949, it would seem time for North Jerseyites to take a lesson from the Otomi Indians of Mexico, who manage to live entirely without water. Of course, the Otomi's secret—the maguey plant—upon which they depend not only for drink but for roof thatch, food, and clothing as well, requires 6 or 7 years to mature, so there is no time to lose. But certainly 6 or 7 years to a sure thing ought to be preferable to another 25 or more of trying to balance, first, North Jersey against South Jersey, then Republican against Democrat, then faction against faction, and finally individual against individual in an effort to reach agreement on something more practical than importing Great Lakes water at somebody else's expense. One trouble with the Otomi system, of course, is that the maguey regime of diet and drink kills most children before they reach the age of 12, primarily from pneumonia or intestinal disease (not, however, waterborne), but with enough water in which to wash at least occasionally, our NJ friends could undoubtedly improve on that record. And there's always a chance that, before things got too desperate, the people who are now agitating to get present reservoirs opened to fishermen will have succeeded in building a few more fishing holes, suitable for incidental use as water supplies.

At any rate, with the water front at the very center of the gubernatorial campaign now being waged, it is undoubtedly only a matter of months until the present problem is—well—taken under consideration. Meanwhile, if North Jerseyites don't like their way, they might try maguey.

New Jersey's frustrations may be mammoth, but it should not be supposed that they are unique, for other areas throughout the country are facing similar problems of water supply development and are encountering similar difficulties and disappointments in realizing their plans. Even California, whose monumental water plan received such wide support last fall, is still only marking time until its north and south can reach a compromise on the transfer of water so that the plan as a whole will be acceptable to the legislature.

Where programs have been small enough to be undertaken by municipalities unilaterally, action has been a little less eventual. Thus, even though

(*Continued on page 42 P&R*)

(*Continued from page 41 P&R*)

the projects required adjudication by the Supreme Court, Los Angeles and New York have been able to put through major water supply developments, and cities such as Charleston, S.C., and Jacksonville, Fla., have been successful with what might be called speculative developments, involving the provision of tremendous excess capacity and its advertising as an attraction to industry. The key to achieving similar success with statewide or interstate developments is undoubtedly public support through public awareness of the relative importance of water supply compared to the interests with which any specific development may conflict. That awareness has been developing slowly, not so much through the efforts of AWWA and its members as through the inconveniences imposed by drought and other inadequacies. And now, through AWWA's new water supply information committee, just under way, through the activities of the Water Resources Council, and through the individual advertisements of many of AWWA's Associate Members, there is hope that a positive development of that awareness will be undertaken. When these coordinated efforts begin to be felt often and everywhere, who knows but that water may finally reach its own proper level in the public esteem. Then, not only our reservoirs, but our cup runneth over.

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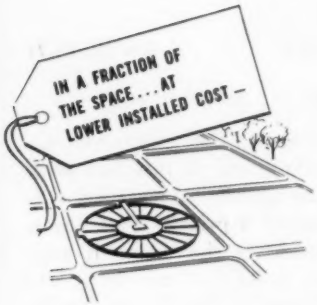
ASEIB—The American Sanitary Engineering Intersociety Board—and its Specialty Committee met Oct. 17–18 and took action on 428 applications for certification. A total of 300 were approved for certification without examination; 50 applicants qualified to take an examination; 44 were rejected; and 34 applications were held over for additional information. Because of the large response occasioned by the Oct. 1 deadline for applying for certification without examination, the limited manpower of the board made it necessary to delay consideration of about 500 applications until the next meeting, in February 1958. Applicants will therefore understand the reason if they do not hear from the Board until after that time.

Louis R. Howson, senior partner in Alvord, Burdick & Howson, Chicago, was installed as president of ASCE during its New York meeting last month. He succeeds Mason G. Lockwood of Houston, Tex. New vice-presidents are Samuel B. Morris, consulting engineer, Los Angeles, and Waldo G. Bowman, editor of *Engineering News-Record,* New York.

(*Continued on page 44 P&R*)



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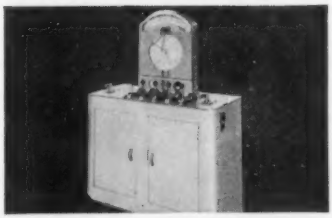

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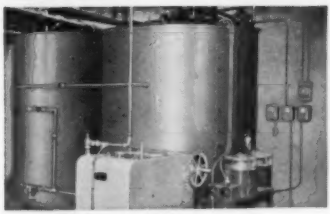

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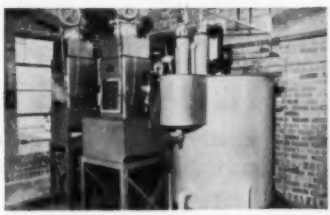

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(*Continued from page 42 P&R*)

Robert T. Browning has been named executive vice-president of Wallace & Tiernan Inc., Belleville, N.J., effective Jan. 1, 1958. He has been associated with the firm since 1930. For the past 4 years he has held the position of vice-president, directing the

sales activities of Wallace & Tiernan's three chemical divisions, as well as the sales and engineering activities of the company's five equipment divisions and subsidiaries.

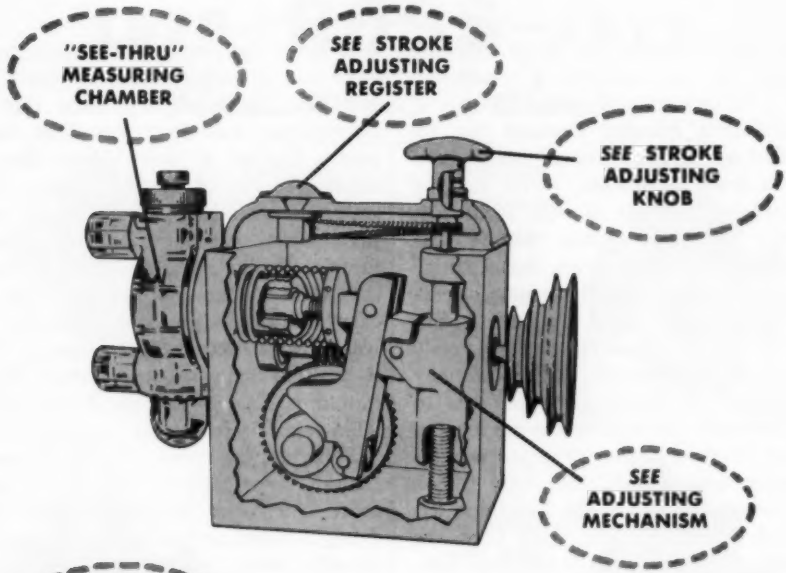
That fluorinews is mostly fluoriviews is a point we've made before—and that fluoriviews seldom, if ever, change is becoming more and more obvious with every collection of communiques from a new fluoridation front. Occasionally, though, out of the mass of information and misinformation that gets into print, some fact or fancy of interest can be extricated:

Facts from our current crop include the rather stale note that the Defense Dept. last December sent a directive to military bases at which children live ordering the fluoridation of their water supplies. As of Jul. 1, there was word that the total number of communities receiving water with adjusted fluoride content had risen to 1,522, with a population served of 31,664,000. Then on Aug. 6, an additional 550,000 population, served by the Minneapolis water system, was added to that total. Later in August, the California supreme court refused to interfere with a state public utilities commission ruling that ordered a private water company to fluoridate the water it supplied to the town of Oroville. And finally last month, the World Health Organization, basing its opinion on studies in 17 different countries, "recommended use of fluoridated water wherever and whenever possible, without qualification or caution."

A little fancier than these cold facts was the news from Frankfurt, Germany, last February, of an effort to reduce tooth decay by catering to a habit long considered a primary cause of caries—by the free distribution of fluoride-impregnated candies to approximately 45,000 children between 6 and 10 years of age. In Canada, meanwhile, the McGill University dental school was conducting an experiment to counteract propaganda concerning the bad taste of fluoridated water. Setting up two fountains at its open house, the school asked visitors to taste and decide which, if either, was supplying fluoridated water. With one of the fountains fluoride free throughout and the other supplying a 2-ppm F^- water for 2 of the 3 days involved, the voting of the 62 per cent perceptive enough to imagine a difference was the expected 50–50 on each of the 3 days. Fanciest, though, of all these scientific revelations concerning fluoridation was that which appeared in a Louisville, Ky., newspaper early in the year, pointing out that "flourine, the most reactive of all the earth's elements makes water burst into flame." Or could "*flour*idation" be even hotter stuff?

On the business side, there was fluoridation fancy, too. First, at Dur-

(*Continued on page 46 P&R*)



SEE THE DIFFERENCE!

See for yourself the design features that make this one particular positive displacement chemical proportioning pump "the established standard of the industry". The cutaway view above shows the simplified internal mechanism of Proportioneers Chem-O-Feeder® which allows "in-motion" infinite adjustment of feed rate . . . plus operation features that put it in a class by itself.

- Provides maximum convenience and control
- Available in simplex, duplex, and triplex models
- Feed rates from 0.2 to 57 GPH
- Discharge pressures up to 125 psig
- Each pumping head can be set independently
- "See-thru" head handles many corrosive liquids
- Other reagent ends available for handling almost all other corrosive liquids

Request Bulletin 1225-2 for complete details. You can rely on the Chem-O-Feeder, the best all-purpose chemical proportioning pump available. Write to **PROPORTIONEERS, INC., 365 Harris Avenue, Providence 1, Rhode Island.**

PROPORTIONEERS
DIVISION OF
B-I-F INDUSTRIES
METERS FEEDERS CONTROLS

(Continued from page 44 P&R)

ham, N.C., where the Rock Springs Water Co. was caught in a squeeze when the city council's consideration of fluoridation boosted demand for its bottled spring water to a point where out-of-town customers could not be supplied. Actually it was from Raleigh, where the public supply was already being fluoridated, that "panic" was reported among those who apparently didn't dare drink tap water. But up at Winnipeg, people were obviously made of sterner stuff, for a company that had developed an apparatus to defluoridate the city water at the tap when the fluoridation program was instituted found itself with only fifteen customers instead of the hundreds expected. And in New York City, the Board of Estimate made headline publishing news by offering copies of the 559-page record of its fluoridation hearings for a mere $279.50—a price all too obviously set by board formula rather than by value of contents.

But it was from the animal world that the news was fancifullest of all. From Down Under, for instance, came word of sheep with wolves' teething—sheep whose teeth had been greatly improved, that is, by fluoridated water, not really to bite back with, but the better to eat with, thereby to improve their health and, more to the point, their wool. And from the salmony shores of Tacoma, Wash., there was news of a scheme to get the fish to bite better by treating Commencement Bay with 180,000 gpd of 0.3 per cent fluosilicic acid solution. Actually this was billed as a waste disposal program, whereby a Stauffer Chemical Co. superphosphate plant arranged to pump its wastes out into the bay through a 300-ft polyethylene pipeline that discharged at a depth of 50 ft during alternate hours of the day, but we who know the proclivities of fishermen have our suspicions. As a matter of fact this isn't the first time that a fluoridating fisherman has been suspect. Earlier it was Harry Krum, superintendent of the Allentown, Pa., water department, whose story was that he was running a test on a new fluoride feeder and, not being authorized to treat the city's supply, had to carry the discharge from the feeder to waste in the Little Lehigh River, which it just so happens, his friends have hinted, is Harry's favorite fishing spot. This really is fluoriruse.

Whether by news, views, or ruse, though, fluoridation continues to rate more newspaper space than even the drought—and continues, too, to grow steadily, now, rather than spectacularly, and in uncatastrophic experience as well as in population served.

Infilco Inc., Tucson, Ariz., has opened a new manufacturing plant at Salem, Ill., augmenting existing facilities in Chicago and Joliet, Ill. The Salem installation will be under the direction of H. J. Leddy, who will also continue as manager of the Joliet foundry division.

Richard S. Engelbrecht, associate professor of sanitary engineering, has been placed in charge of the sanitary engineering research and teaching program in the Dept. of Civil Engineering, University of Illinois, Urbana. Dr. Engelbrecht succeeds Prof. J. C. Dietz, who resigned to become a partner in the consulting firm of Clark, Daily & Dietz, Urbana.

John L. Black has been named supervisor of Allis-Chalmers' Industrial Press Section. He has been with the company since 1951.

(Continued on page 48 P&R)

1879—ROSS—1879

Automatic Valves

ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting

Maintains safe operating pressures for conduits, distribution and pump discharge

SURGE-RELIEF VALVE

REDUCING VALVE

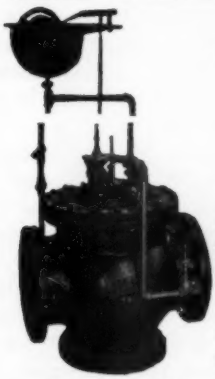
Maintains desired discharge pressure regardless of change in rate of flow

Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

A self contained unit with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.

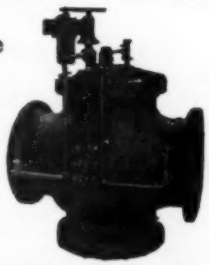


FLOAT VALVE

Maintains levels in tank, reservoir or basin

1. As direct acting
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

Electric remote control—solenoid or motor can be furnished



REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

Packing Replacements for all Ross Valves Through Top of Valve

ROSS VALVE MFG. CO., INC., P. O. BOX 593, TROY, N.Y.

(*Continued from page 46 P&R*)

HEJ Scholars 1 & 2, Paul A. Kuhn and Marvin R. Lindorf, first and second winners of the Harry E. Jordan Scholarship Award, which was established in 1954 by the Water & Sewage Works Manufacturers Assn., have now both come home to roost—home to the engineering field, that is, and home to water work as well.

From Paul Kuhn, 1955 Awardee, who became the father of a new male engineering prospect last May 5, came word in July:

> My work at Stanley Engineering Co. [Muscatine, Iowa] is going very well. In accordance with their policy of rotating new engineers in various assignments in the company, I was recently transferred to the Report Group, where I am presently assigned to the Industrial Section. My first job here again was a water problem. I am working on the development of a small ground water supply for cooling water in an industrial plant. This job so far has involved drilling a test well and test pumping.

And from Marvin Lindorf, 1956 Awardee, who became the father of a second boy on Aug. 8, has come the news:

> I completed my graduate work in May and received my degree in June. As you may recall, I have been working on an analysis of water treatment costs in California. As a result, Professor Orlob and I have prepared a paper, which we are submitting to the JOURNAL [to be published in an early issue].
>
> As you know I was working part time for Kaiser Engineers during the school year. I have continued with Kaiser in the capacity of Job Engineer in the Structural Division. In October, however, when my current project is completed, I will be transferred to the Sanitary Design Section of the Civil Division. In this new assignment I will be responsible for planning and design of water and sewer systems for various industrial applications.

Impressed with the good start in sanitary engineering that our first scholars have achieved, we can't help also being impressed with their success at family engineering. Thus will the engineer shortage certainly be solved.

Ground water supplies are available in moderate to very large quantities in different parts of the lower Delaware River Basin, according to a recently released US Geological Survey report covering a 4,600-sq mile area that lies mostly within a 40-mile circle centered in Philadelphia. More than 200 mgd of ground water is used in the region at present, and it is estimated that an additional 1 bgd can be developed.

As part of the ground water used is replenished by induced recharge from the Delaware River, the latter is an important factor in ground water quality. The proposed deepening and widening of the river channel would enhance the opportunity for interchange of water between the river and the aquifers. The report indicates that, except in small areas where there is manmade pollution or where salt-water encroachment has occurred, the chemical quality of the ground water is excellent for all ordinary uses.

Entitled "Ground Water Resources in the Tri-State Region Adjacent to the Lower Delaware River," the report was written by H. C. Barksdale, D. W. Greenman, S. M. Lang, G. S. Hilton, and D. E. Outlaw. Pending publication by the New Jersey Dept. of Conservation & Economic Development, copies may be inspected at USGS offices in Washington, Harrisburg, and Trenton, or at Incodel, Suburban Station Bldg., Philadelphia.

(*Continued on page 50 P&R*)

SAVE SPACE – SAVE COSTS

AWWA 48", 125# valve for drop-tight shut-off at 100 psi. Renewable rubber seat; hydraulic cylinder operator.

AWWA 60", 50# valve for drop-tight shut-off at 35 psi water pressure. Cast iron body with spool type rubber liner; with worm gear and handwheel operator.

with

W. S. ROCKWELL

Butterfly Valves

Built to Meet All AWWA Specifications

- Compact—Lighter Weight
- Reduced Installation Space
- Lowest Installed Cost
- Efficient Reliable Operation
- Drop-Tight Shutoff
- Minimum Restriction to Flow
- Minimum Pressure Drop
- Non-Clogging
- Better Control—Manual or Automatic
- Less Maintenance

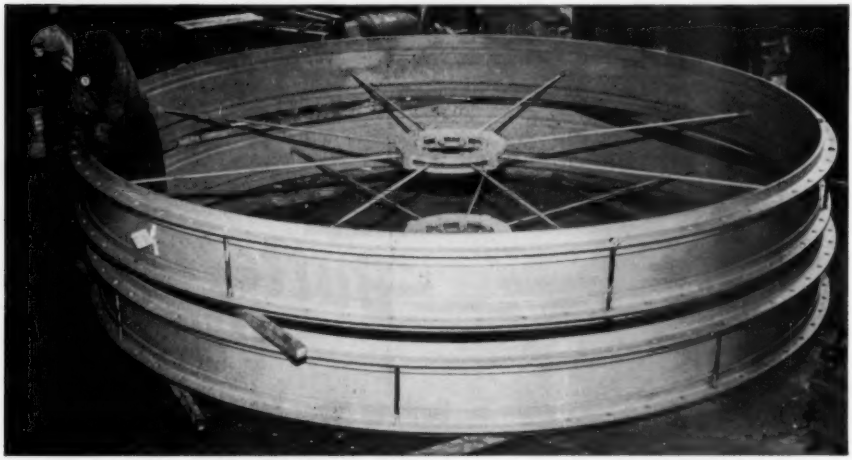
W. S. Rockwell Butterfly Valves are made in all standard sizes of cast iron, cast steel, stainless steel, bronze or other alloys; natural or synthetic gum rubber seat with clamping segments, or spool type rubber liner extending over flange faces. Operators—manual: AWWA nut, handwheel, chain wheel or other types; automatic: electric motor or cylinder. Write for Bulletin 574.

ROCKWELL SINCE 1888 BUILT

W. S. ROCKWELL COMPANY

2607 Eliot Street — Fairfield, Connecticut

(Continued from page 48 P&R)



151½ inches is the size of the coupling shown above, produced by Dresser Mfg. Div., Bradford, Pa. Said to be the largest single ring design coupling ever manufactured (weight 2,370 lb), it was ordered by Thompson Pipe & Steel Co. for the turbine inlet pipe of a penstock at the Glendo Dam Power Plant in Wyoming.

A 'shower' has long been recognized as strictly a female affair, reserved primarily for the prospective bride or mother, but during these droughtbound days in Connecticut rural areas, families lucky enough to have a flowing well are giving mixed showers for their less fortunate friends —that is to say, the invitations usually read "a bath and dinner." "Just like the good old days when water was free" did someone say?

Louis C. Bishop has been named district manager for the Pittsburgh sales office of Hagan Chemicals & Controls. He succeeds Thomas M. Nourse, who has been appointed head of central station sales.

Tails win, it seems. It's really none of our business, but the announcement *was* addressed to the JOURNAL and we do have a definite feeling about uprumpitude, so we pass along the word that the Industrial Designers' Institute 1957 design award has gone to Chrysler Corp. "for their establishment of a continuity of design which reflects with distinction the spirit of 1957 Chrysler Corporation cars." "Continuity," yes, but that this emphasis on the rear end is a "forward look," either puzzles or dismays us. Tails, it is, though, and ours is down.

H. E. Hudson Jr., head of the Detroit office of Hazen & Sawyer, consulting engineers, has become a partner in the firm.

Clifford F. Rassweiler, vice-chairman of the board and vice-president for research and development, Johns-Manville Corp., has been awarded the Chemical Industry Medal by the Society of Chemical Industry, "for conspicuous services to applied chemistry."

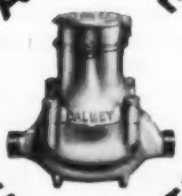
(Continued on page 52 P&R)

You Can
COUNT
on it

CALMET

oscillating-piston type
WATER METERS
give you
DEPENDABLE
YEAR 'ROUND
SERVICE

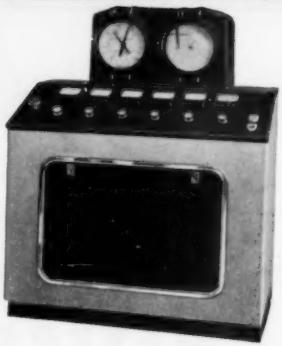
CALMET
WATER METER



MANUFACTURED BY
WELL MACHINERY
& SUPPLY CO., INC.
FORT WORTH, TEXAS

TRANSITE FILTER BOTTOMS

Cut Your Filtration Costs



FILTER OPERATING TABLES for Modernizing EXISTING PLANTS

Designed to *eliminate cables* that have beset operators for years, the new Filtration Equipment Corporation control tables fit all specifications for standard operating procedures and can be adapted to special needs.

Planned around the experience of engineers and operators, these tables are pleasing in appearance, of durable construction, and can be easily installed and maintained.

Write For Literature

FILTRATION EQUIPMENT CORPORATION
271 HOLLENBECK ST.
ROCHESTER 21, N. Y.

(*Continued from page 50 P&R*)

Emile J. Fricker has retired as vice-president of Hackensack Water Co., Weehawken, N.J., after 16 years in the post and a total of 49 with the company. He has recently been in charge of assembling the real estate for De Forest Lake Reservoir, the firm's newest water storage area in Rockland County.

Close to the chest is the way the Army is playing it these days as far as bacteriological sampling is concerned, having adopted a vest worn next to the skin for use of its bacteriologists in incubating field test samples at body temperature while carrying them back to the laboratory. Invented and patented by four scientists at the Army Chemical Corps Biological Warfare Laboratories, Fort Detrick, Frederick, Md., the vest is fitted with three rows of seven flap-covered pockets set between two inner porous layers in the vest. A layer of metal-coated fabric to reflect heat and an outer layer of heavy cloth protect the contents from outside weather. The pockets are designed to accommodate a small plastic Petri dish containing a membrane filter and a bacterial nutrient.

What bothers us just a bit about the Army's description of this new uniform item is the point that "it may be worn during sleep or passed from one wearer to another." The very thought of passing germs around this way or of crawling into bed with them sounds frightfully unsanitary, particularly to one who thrashes around in his sleep as we do. Which leads us to suggest that, for hotheaded day-shift bacteriologists anyway, an incubation helmet might be considerably more acceptable.

Imagine a soldier with a 7-hr *Esch!*

(*Continued on page 54 P&R*)

Rugged Concrete Pipe Withstands the Severe Stresses of Jacking Operations

The photo shows 84-in. concrete pipe being jacked under several railroad tracks to provide protection for a 48-in. water main of the Metropolitan Utilities District in Omaha. The only interference with normal traffic was the observation of a "slow order."

This is another example of how sturdy concrete pipe meets almost any combination of site or soil conditions or drainage requirements. Concrete pipe also resists heavy traffic impact, high fill loads and severe climate.

Jacking concrete pipe minimizes roadbed disturbances under roads, streets and railroads. This saves money by reducing or eliminating costly maintenance often caused by trench fill settlement.

Besides great strength and easy installation concrete pipe offers:
1. MAXIMUM HYDRAULIC CAPACITY—assured by smooth interior walls, clean, even joints and freedom from damaging internal corrosion.
2. EXTRA LONG LIFE—proved by long years of dependable service in thousands of installations.
3. LOW-ANNUAL-COST ECONOMY—resulting from its moderate first cost, long years of service and little or no maintenance expense.

PORTLAND CEMENT ASSOCIATION
A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work
33 W. Grand Ave.
Chicago 10, Ill.

(*Continued from page 52 P&R*)

Rockwell Mfg. Co. has added 27,000 sq ft, including new engineering facilities, to its water meter plant at Uniontown, Pa., as part of the firm's current expansion program. The Dubois, Pa., gas meter plant has also been enlarged.

The Soviet Sputnik may be champion of outer space; the Milwaukee Braves may be champions of the world, but *all* is not lost—the Southern California Water Co. is still champion of the *Financial World* annual report competition, and when the bronze "Oscar of Industry" was presented to the company at an awards banquet in New York last Oct. 28, it marked the sixth time that the company's report had been selected best in its field. Thus, to C. P. Harnish, president, and to B. M. Thompson, purchasing agent and annual reporter, we offer congratulations, not only for prolonging the SCWCo. reign in a year that has been rough on champs, but for dispelling that sudden feeling of ours that the best is none too good.

One of 5,000 annual reports entered in the 100 industrial classifications involved, the Southern California report won out in the water works groups, with Jamaica Water Supply Co.'s in second place and Indianapolis Water Co.'s in third. Perpetually at the top of the report league, these three companies give each other spirited competition for each year's Oscar. As a matter of fact, from the Jamaica utility, which serves part of New York City's

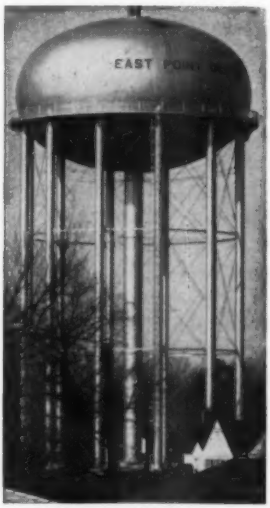
(*Continued on page 56 P&R*)

ELEVATED WATER TANKS

Built in accordance with AWWA specifications, in all sizes and various types.

Send us your inquiry—stating capacity, height to bottom and location. Established 1854. Write for bulletins.

R. D. COLE MANUFACTURING CO. COLE NEWNAN, GEORGIA

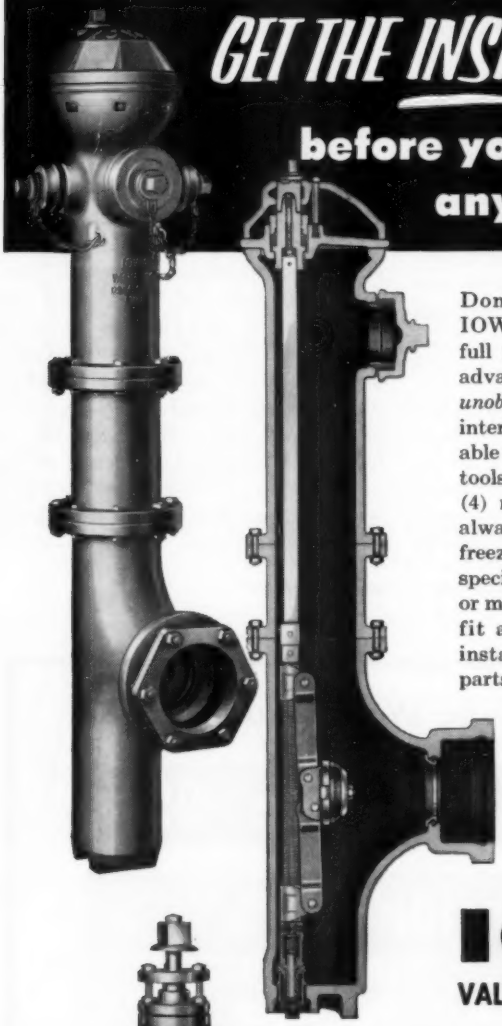


COLE Ovaloid Type

R. D. COLE MFG. CO.
NEWNAN, GEORGIA

GET THE INSIDE STORY

before you specify any hydrant!

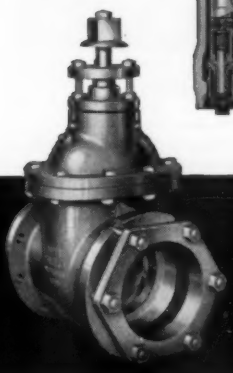


Don't buy blindly! Only in IOWA hydrants do you get full measure of such practical advantages as: (1) absolutely *unobstructed* waterway; (2) all internal working parts removable through top; (3) no special tools needed for maintenance; (4) no binding or distortion, always easily opened; (5) no freezing; (6) meet all A.W.W.A. specifications; (7) bell, flange or mechanical joint connections fit any existing or planned installation; (8) replacement parts always available.

that's why farsighted city officials choose

IOWA

VALVES AND HYDRANTS



for COMPLETE details, address:

IOWA

VALVE COMPANY

A Subsidiary of James B. Clow & Sons, Inc.

Oskaloosa, Iowa

(*Continued from page 54 P&R*)

Borough of Queens, we have already heard a challenging "wait till next year," a slogan which it may have inherited from a Southern California competitive group formerly resident in neighboring Brooklyn. Meanwhile, the plans for Indianapolis sound familiar, too, with their call for more and better "pitchers."

Not Sputnik but a spitknuckler was what done us in, though—Break up Burdette!

George really lay down on the job last month at Clyde, N.Y., and as a result, 400 GE employees had to be sent home for 4 hr, the Hemingway Canning Co. had to struggle through on a limited schedule, and Sheffield Farms had to send its farmers home disgruntled, with unwashed milk cans. George, of course, is that proverbial person whom everyone lets do it—and who always does, it seems. Finally, at Clyde on Aug. 16, he had apparently had enough, for when a car crashed into a hydrant in town and started a real gusher, not one of the rescuers, residents, or sidewalk superintendents bothered to call the water company—nor did George. Thus, the town's 200,000-gal tank was drained dry and, particularly, the town's industries suffered until the supply could be restored. Once the supply was exhausted, of course, there was no lack of Georgians. Next break, we'll bet, won't be one for the water company telephone operator.

(*Continued on page 82 P&R*)

for Public Water Fluoridation

Sodium Silicofluoride – 99%

(Powder)

Sodium Fluoride – 98%

(Powder or Granular)

Meet AWWA specifications

White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
Minimum of dust in handling

THE AMERICAN AGRICULTURAL CHEMICAL COMPANY

50 Church Street, New York 7, N. Y.

AA QUALITY

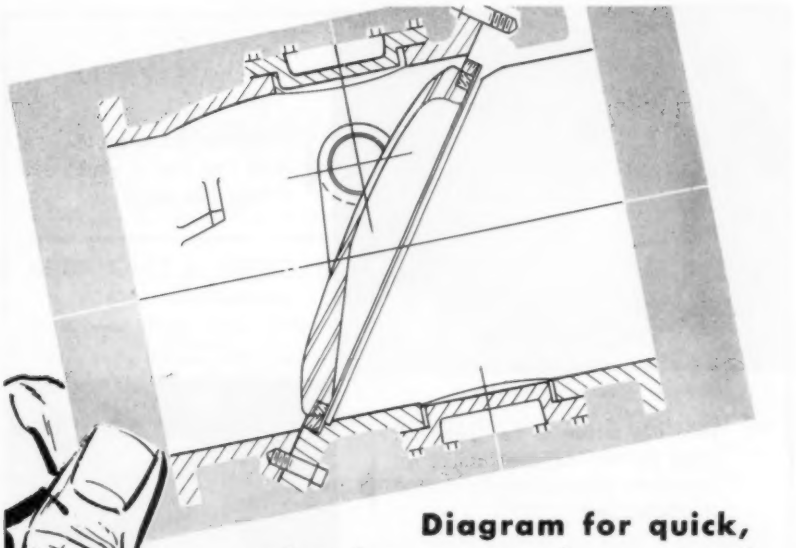


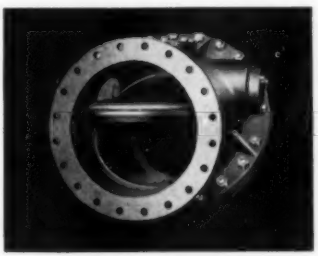
Diagram for quick, quiet, low-cost valve operation

Here's the picture . . . a cross section showing the working principles of the Chapman Tilting Disc Check Valve. It makes sense. It's a clear-cut diagram of a way to save dollars.

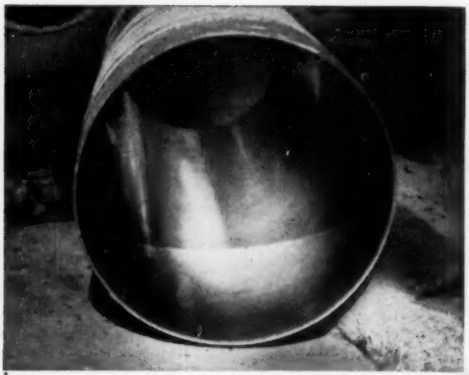
Notice the body design — plenty of room allowed to eliminate flow resistance, and the balanced "Airfoil" disc supported on a pivot. When the flow is on, disc opens wide enough to meet the demands of the flow. When the flow is off, disc drops quickly to a firm, tight seat. This is not only quick operation . . . it's quiet operation. There's no flutter. No banging. No slamming. No scraping of disc and seat. All this, of course, means low-cost operation. There's nothing to cause wear and tear or damage to valve or system. Your maintenance costs are low even under severe conditions.

CHAPMAN
Tilting Disc Check Valve

For best results in handling fluids or gases at the lowest cost, specify Chapman Tilting Disc Check Valves. They cover a wide range of pressures and are available in iron or steel. You'll find them all with complete data in our Catalog 30-A. Write for your copy, now.

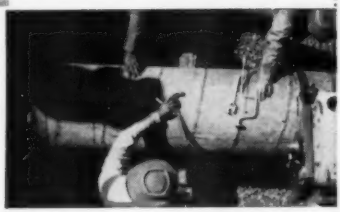


The CHAPMAN Valve Manufacturing Co.
INDIAN ORCHARD, MASSACHUSETTS



Unretouched photograph of Armco Pipe after 17 years in water line service.

When this section of the 17-year-old Armco Pipe was uncovered, coating on the exterior showed practically no sign of deterioration.



Spartanburg, South Carolina, Finds 17-Year-Old Armco Pipe Good as New

In 1939, the city of Spartanburg, South Carolina, installed 40,000 feet of Armco Welded Steel Pipe for a water line. In 1956, contractors removed a 5½-foot section of the 17-year-old pipe to insert a tee connection.

The unearthed section (shown above) still had its original smooth lining. In 17 years there had been *no loss of flow* capacity. The pipe line is good for many, many more years of dependable service.

You will find that Armco Pipe offers you many other advantages. It is supplied in a wide range of diameters, from 6 to 36 inches; wall thicknesses from 9/64- to ½-inch; lengths up to 50 feet. Coatings are supplied to AWWA specifications.

Write for prices and delivery time. Armco Drainage & Metal Products, Inc., Welded Pipe Sales Division, 4827 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: write Guelph, Ontario.

ARMCO WELDED STEEL PIPE

Professional Services

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates

Three Penn Center Plaza Philadelphia 2, Pa.

ALVORD, BURDICK & HOWSON

Engineers

Water Works, Water Purification, Flood Relief, Sewage Disposal
Drainage, Appraisals, Power Generation

20 North Wacker Drive Chicago 6

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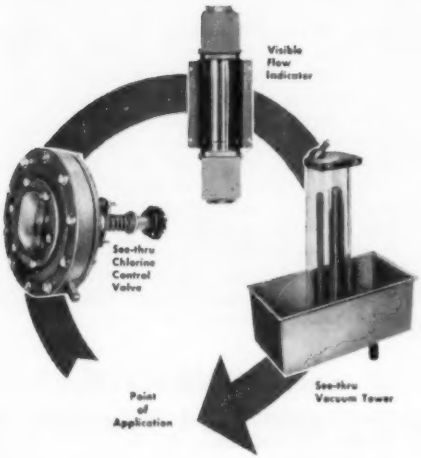

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

FILTRATION

Cleaning of Large Sand Filters. J. Doudert. Tech. Eau (Brussels), No. 101, p. 37 ('55). Standard methods for cleaning sand filters are described. Author then gives illustrated description of selector invented by Sivade, which serves to separate mud from sand; operation of selector is outlined. Selector has been installed by General Water Co. to serve several of large filtration plants which supply Paris with water.—*WPA*

Microstraining and Ozonation—Middleton Pond Pilot-Plant Studies. R. M. Soule. Sanitalk, **4**:6 ('56). Pilot scale microstraining unit and ozonator have been installed at Danvers, Mass., water treatment plant to treat water from Middleton Pond. Microstrainer removes amorphous matter and microorganisms and ozone treatment reduces color, odor and taste of water; records show that both units are efficient and economical. —*WPA*

The Development of Biological Filtration. H. H. Stanbridge. Water Sanit. Engr., **6**:18 ('56). Survey on effects of temp. on ventilation, effects of O on biol. filtration, different methods used to evaluate performance of biol. filter, and different methods of employing biol. filtration.—*CA*

Relation of Performance Characteristics of Sodium Cationite Filter to Conditions of Cationite Regeneration. B. E. Kasinov. Vsesoyuz. Zaochnyi Politekh. Inst., Sbornik Statei (USSR), No. 11, p. 65 ('55). Detailed discussion of assembly of a lab. filter, general conditions and technique for conducting work, results of testing lab. cationite filter, selection of optimum conditions for cationite regeneration, and construction of actual water softener. Counter-current method for base exchange gives more efficient H_2O softening than does the direct-flow method; optimum concn. of NaCl soln. for regeneration is 6–8%. Economy of operation of cationite filter can be increased by use of residual absorption capac. of filter. —*CA*

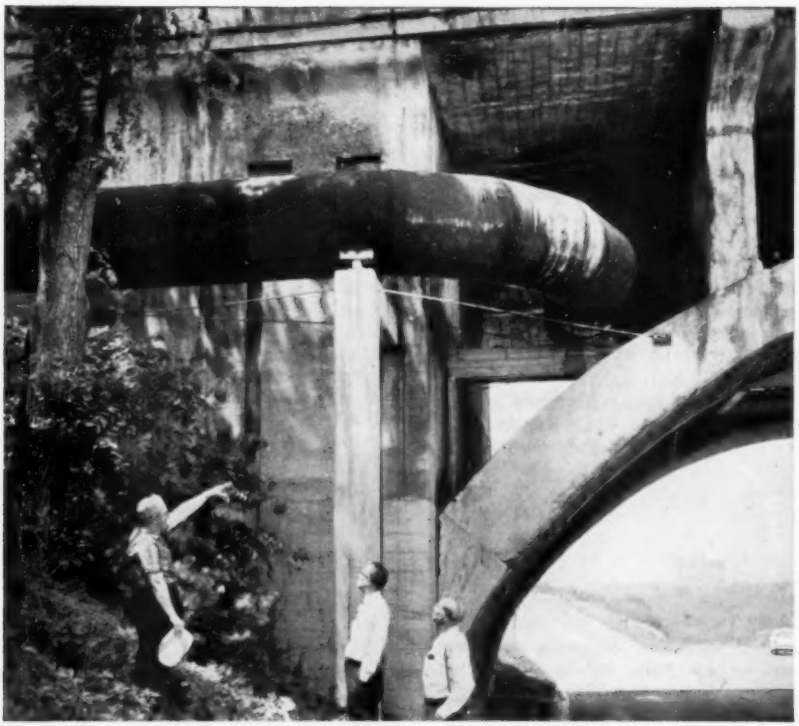
River Water Filtration. A. E. Zdansky. Dechema Monograph. (Ger.), **28**:130 ('56). New pptn. process is described which is considerably simpler and cheaper than one using metal salts. Essence of process is application of cast-iron chips as means for colloidal pptn. It is sufficient to filter unpurified H_2O through layer of Fe chips or shavings, thus producing substantial formation of $Fe(OH)_3$. Only 20–25% O satn. is required to ppt. colloidal part of turbid H_2O. Treated, clear H_2O is approx. 70% satd. with O, therefore no after-aeration is necessary. App. is illustrated.—*CA*

FLUORIDATION

The Conclusion of a 10-Year Study of Water Fluoridatien. D. B. Ast & E. R. Schlesinger. Amer. J. Publ. Hlth., **46**:265 ('56). Authors review briefly results of 10-yr study carried out in Newburgh-Kingston area, N.Y., on fluoridation of water in relation to incidence of dental caries. Additional information on safety of water fluoridation has been obtained from tests carried out on children: knowledge of blood fluoride levels, of rate and mechanism of urinary excretion of fluoride, and of magnitude and mechanism of bone deposition increases understanding of some important biol. effects of toxic doses of fluorides.—*WPA*

Ten Years of Fluoridation. J. R. Forrest. Monthly Bul. Ministry Health Lab. Serv., 15:79 ('56). It is stated that it is now established fact that ingestion of naturally

(*Continued on page 68 P&R*)



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(Continued from page 66 P&R)

occurring fluorides from drinking water effects marked reduction in incidence of dental caries, and that with concn. of about 1 ppm fluoride in water this reduction is about 60%. Studies carried out at Newburgh, N.Y., Grand Rapids, Mich., and Brantford, Ont., over 10 yr with fluorides added to water supplies in concn. of 1.0–1.2 ppm, have shown that same beneficial effect may be obtained by fluoridation, without proving in any way detrimental to health of consumers. Some details of dental, pediatric, and other medical aspects of Newburgh study are given.—*WPA*

The Brantford-Sarnia-Stratford Fluoridation Caries Study. 1955 Report. H. K. BROWN ET AL. Can. J. Publ. Health, **47**:149 ('56). Detailed report is given of study made at Brantford, Ont., on effect of fluoridated water on incidence of dental caries in children; at Brantford sodium fluoride is added to water supplies to give fluoride concn. of 1 ppm. Teeth of similar age groups were also examined at Stratford, where water supply in use since 1917 has contained naturally occurring fluorides in concn. of 1.6 ppm, and at Sarnia where concn. of fluorides in water supply is negligible. Report shows that children born in Brantford since fluoridation program was started in 1945 now exhibit same degree of resistance to dental caries as those of corresponding age in Stratford; that significant reduction in dental caries, not evident in Sarnia and Stratford, has occurred in all age groups studied at Brantford; and that no dental or general health ill effects have resulted from consumption of fluoridated water.—*WPA*

Final Report of Local Studies on Water Fluoridation in Brantford. W. L. HUTTON, B. W. LINSCOTT & D. B. WILLIAMS. Can. J. Publ. Health, **47**:89 ('56). Final report on local studies of fluoridation of public water supply of Brantford, Ont., is given, after completion of 10 yr of water fluoridation: an interim report was published after 5 yr. Safety, cheapness, and ease of application in water works practices of fluoridation, and its beneficial effect on teeth of children have been demonstrated. Tables are given summarizing changes in incidence of dental caries from 1944 to 1955.—*WPA*

Urinary Excretion of Fluoride Following Defluoridation of a Water Supply. R. C. LIKINS, F. J. MCCLURE & A. C. STEERE. Public Health Repts., Wash., **71**:217 ('56). It has been shown that all absorbed fluoride is eliminated in urine or deposited in skeletal and dental tissues, and that reduction in fluoride intake mobilizes that deposited in skeleton. It is not certain, however, whether or not any factors other than reduction in intake of fluoride influence mobilization of fluoride. Expts. were carried out in Bartlett, Tex., to investigate relationship of age to rate of mobilization of fluoride in humans given excessive amount (8 ppm) of fluoride in water supplies. Procedure for investigation, which was carried out on both children and adults, is described, and results are given in tables. These indicated that urinary excretion of fluoride remained high even after marked reduction in fluoride intake. There was, however, no relation between age and urinary fluoride excretion in either children or adults, although extent of mobilization was greater in children.—*WPA*

State of Fluoride in Drinking Water. I. FELDMAN, D. MORKAN & H. C. HODGE. J. Dental Research, **36**:192 ('57). In any drinking water supply with pH of 5 or higher, and fluoridated with $\leqq 16$ ppm F as Na_2SiF_6, complete hydrolysis occurs to silicic acid, F ion, and HF. On ingestion, all F enters blood stream as F ion. Toxic action of SiF_4 or SiF_6^{--} is excluded. Of the metallic ions in drinking water, only Ca and Mg are present in sufficient concn. to bind at least 1% of any F.—*CA*

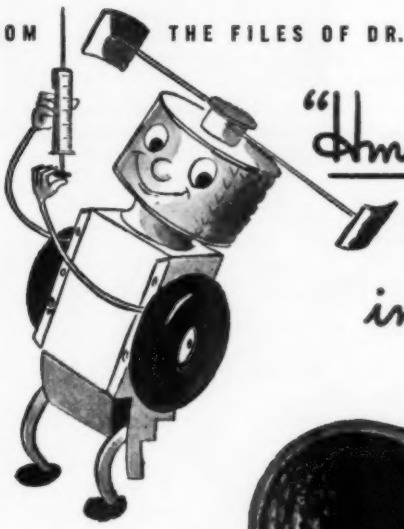
WELLS AND GROUND WATER

The Principal Processes in the Formation of Chemical Composition of Underground Waters. A. A. BRODSKII. Gidrokhim. Materialy (USSR), **24**:107 ('55). Processes influencing formation of chem. compn. of underground waters are reviewed.—*CA*

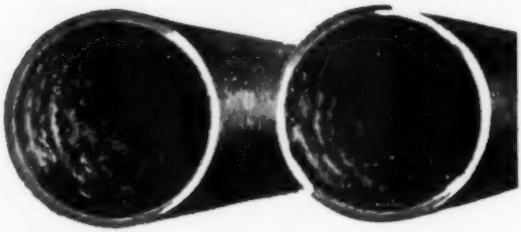
Formation of Underground Carbonic Acid Waters. A. A. SMIRNOV. Gidrokhim. Materialy (USSR), **24**:101 ('55). Facts which seem to contradict existing theory that underground carbonic acid waters are of juvenile origin are reviewed, and new inter-

(Continued on page 70 P&R)

FROM THE FILES OF DR. CENTRILINE...



"Hmmm-Leakage! This calls for immediate consultation"



CASE #1687

PATIENT: 5 miles of 62" and 36" steel water mains in St. Louis, Missouri.

SYMPTOMS: Leakage repair costs on the increase from 1936 to 1947.

DIAGNOSIS: External corrosion causing pitting through the pipe wall.

TREATMENT: In 1947, after consultation with Centriline, pipelines were cleaned and cement-lined in place with a smooth, dense mortar lining by the Centriline Process.

RESULTS: The dense cement lining stopped leakage, eliminating high maintenance costs. Savings represented 13% return on the cost of cleaning and lining.*

This lining has paid for itself in only 8 years. Not only was the leakage stopped but the carrying capacity was increased. If your problem is leakage in steel pipe . . . or capacity reducing tuberculation in steel or cast iron water mains, consider the advantages of cement lining in place.

*From a paper written by Mr. John B. Dean, Division Engineer, Water Div., St. Louis, Mo.

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(Continued from page 68 P&R)

pretation of problem is discussed. It is concluded that CO_2 of underground carbonic acid waters originates in the atmosphere. —*CA*

Origin of the Saline Composition of Cave Waters. S. A. Durov. Ukrain. Khem. Zhur. (USSR), **22**:106 ('56). New calcn. method and "lever rule," geometrical method, are used to show that compn. of cave waters is frequently unrelated to dissolving property of H_2O, as previously thought, but rather due to oxidation of sulfides and action of H_2SO_4 and Fe sulfates on surrounding rocks (mostly carbonates).—*CA*

The Solubility of Iron in Subterranean Waters. M. Schoeller. Ann. Inst. Hydrol. et Climatol., **26**:1 ('55). Theoretical relations are given that connect total Fe content and activities of Fe^{++}, Fe^{+++}, and $FeOH^{++}$ with pH, oxidation-reduction potential, and activity of HCO_3^-. Conditions required for pptn. of $Fe(OH)_2$, $Fe(OH)_3$, $FeCO_3$, and FeS in subterranean waters are derived. Relation of soln. of Fe and its extent to nature of ground and geol. condition are discussed.—*CA*

The Recharge of Ground-Water—Problems and Dangers. A. Key. Surveyor (Br.), No. 3380, p. 116 (Feb. '57). Advantages and disadvantages of ground water recharge are listed. Purifying capac. of soil is discussed. Mention is made of pretreatment practices, and means of detg. vertical and lateral percolation rates. Article is concluded with list of questions concerning engineering, costs, administrative problems.—*PHEA*

Chemical Composition of Underground Waters. A. Herman. Bul. Centre Belge Etude et Document. Eaux (Liege), **34**:240 ('56). Review is given of ionic migration in underground waters and of theories of sediment formation from these ions. [1] Chem. properties of water in contact with various rocks or soils depends on mobility of ions and pH. [2] Elements leached out by water redeposit as sediments in definite order, which depends on nature of elements in soln. [3] There is definite relation between soil, subsoil, and underground waters, which depends on their salinity indexes. [4] Dissoln. and pptn. of elements also depend on dissolved O and interaction of ascending and descending currents.—*CA*

Method of Rapid Microvolume Analysis of Ground Waters, Water Samples, and Solutions in Soil of Salted-up Regions. M. P. Polyakov. Gidrokhim. Materialy (USSR), **24**:41 ('55). Titration with Trilon B is best for identifying Ca and Mg; direct titration with $BaCl_2$ in presence of tetraoxyquinone as indicator is best for SO_4^{--}; usual volumetric methods are used for O_3^{--}, HCO_3^-, and Cl^- ions. It is more accurate to det. Mg from difference between general hardness and Ca^{++} concn. General hardness is titrated by Versene with Black Eriochrome T; Ca hardness by Versene with murexide as indicator. To titrate Mg directly (with Ca as difference), its hardness is obtained from Versene with Eriochrome Black T as indicator (after adding excess oxalate liquid) in presence of pptd. Ca oxalate. Elec. cond. as control magnitude is good, needing few min. and 3–12 ml liquid, with little effect from colloids; but if concn. exceeds 0.001 *N*, soln. must be dild. —*CA*

Chemical Processes in Ground Water Wells. H. J. Boorsma. Gas. u. Wasserfach (Ger.), **98**:440 ('57). In addn. to FeOH stoppages reported, deposits of $CaCO_3$ or Fe compds. may be due to reduction of pressure on water, causing evolution of CO_2 and disturbance of equil. For deposition of $CaCO_3$ to occur in above instances, it is necessary that underground water be under pressure and that it be near or at CO_2-lime equil. point. Furthermore, process can be assisted by release of other dissolved gases, which will tend to wash CO_2 out of water. —*CA*

Evaluation of Ground-Water Tracers. W. J. Kaufman & G. T. Orlob. Trans. Am. Geophys. Union, **37**:297 ('56). Lab. studies on 3 soils using fluorescein, chloride, and I^{131} as iodide; and field studies on sand and gravel aquifer using fluorescein, chloride, dextrose, and I^{131}, indicate that none of tracers studied is completely satisfactory for every situation. Cationic materials, including radioisotopes and certain org. dyes, are generally unsatisfactory for depicting movement of water through porous medium be-

(Continued on page 74 P&R)

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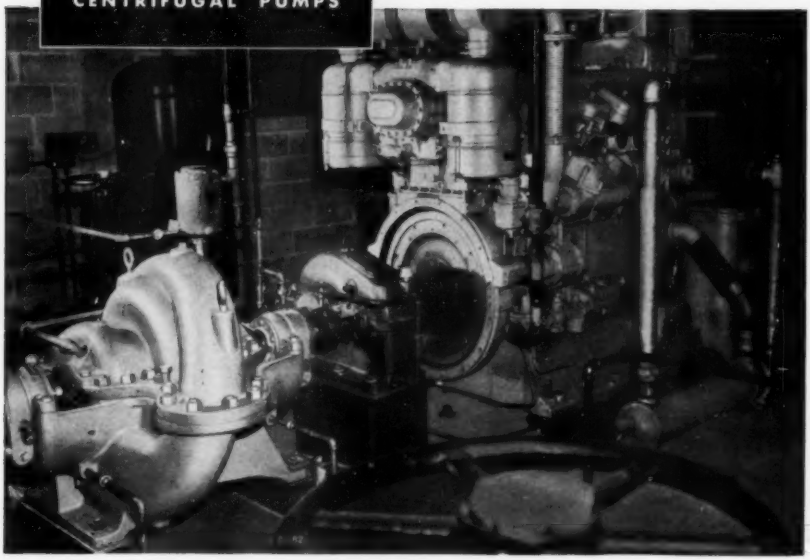
TWO-STAGE CENTRIFUGAL PUMPS

boost pressure at peak loads in Port Washington, New York



This De Laval two-stage horizontal split-case pump is one of a pair used to boost pressure during peak hours in the Port Washington, New York water works. Taking water from a large underground storage tank, these De Laval units maintain pressure throughout the system. The dependable centrifugal pumps are powered by Caterpillar diesels with speed increasers; they deliver 1500 gpm at 400 feet tdh with 15 feet lift requiring 185 bhp.

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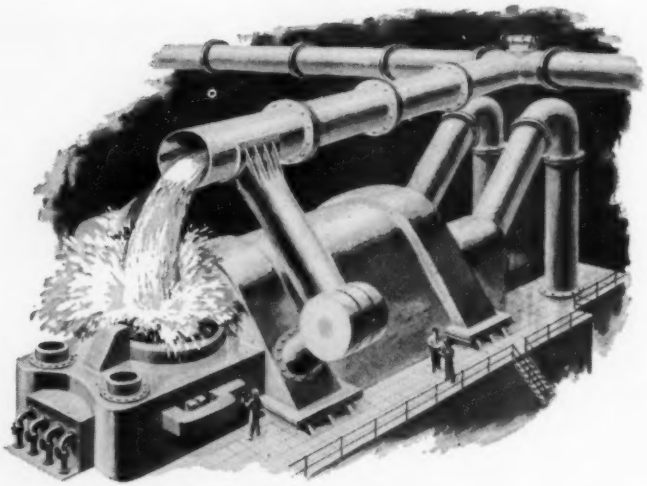

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And, like Oliver Twist, industry constantly calls for "More." 18 barrels of water to make one of oil. 365,000 gallons to produce a ton of rayon. 250 tons for one of wood pulp. And every ton of coal we burn for steam and power requires another 600 to a thousand tons of water!

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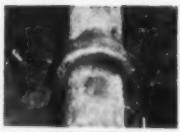

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pipe FOR MODERN WATER WORKS

(*Continued from page 70 P&R*)

cause they modify transmission characteristics of system. Anionic radioisotopes may be largely retained by adsorption when used without stable carriers. Chloride may be satisfactorily used where diln. effects can be avoided and dispersion of clays is not likely. Org. materials are subject to decompn. by soil microorganisms and hence their value as water tracers is limited. Tracer may exchange with soil-bound water when used as tritiated water, with a resulting reduction in veloc. of tracer front.—*CA*

FOREIGN WATER SUPPLIES —GENERAL

The Lusaka Water Supply Scheme. P. H. F. PAGE. Wat. & Wat. Eng. (Br.), **60**:384 ('56). Water for Lusaka, capital of Northern Rhodesia, is pumped from 24-in. boreholes, aerated to remove free carbon dioxide, chlorinated, and pumped to elevated 300,000-gal storage tank which will provide 50-ft pressure during periods of peak demand. When construction is complete aerated water will pass to softening plant consisting of vertical-flow reaction tanks for treatment with excess lime and aluminate. Sludge from tanks will be recirculated and concd. sludge passed to lagoon beds. Small proportion of water will not be softened and this will be blended with softened water in contact chamber where superchlorination will take place. Water will then pass through rapid sand filters to pure water tank. Water leaving this tank will be dechlorinated with sulfur dioxide and distributed by gravity through steel mains. At present, scheme supplies 2.5 mgd which will be increased to 5 mgd by addn. of 2 further boreholes. Flow diagram of plant is given.—*WPA*

Pitsford Water Supply Scheme. Engineer (London), **202**:646 ('56). To augment water supply for Mid-Northamptonshire Water Board, reservoir with capac. of 4 bil gal has been constructed on Pitsford stream, a tributary of Brampton branch of river Nene. Reservoir will yield about 4 mgd in dry weather. Compensation water will be dischgd. at rate of 0.2 mgd in winter and 0.6 mgd., in summer. Intake will later be constructed on Kislingbury branch of river Nene, from which water will be pumped to reservoir, and this should double yield of scheme. Water will be treated by coagulation, sedimentation, and filtration.—*WPA*

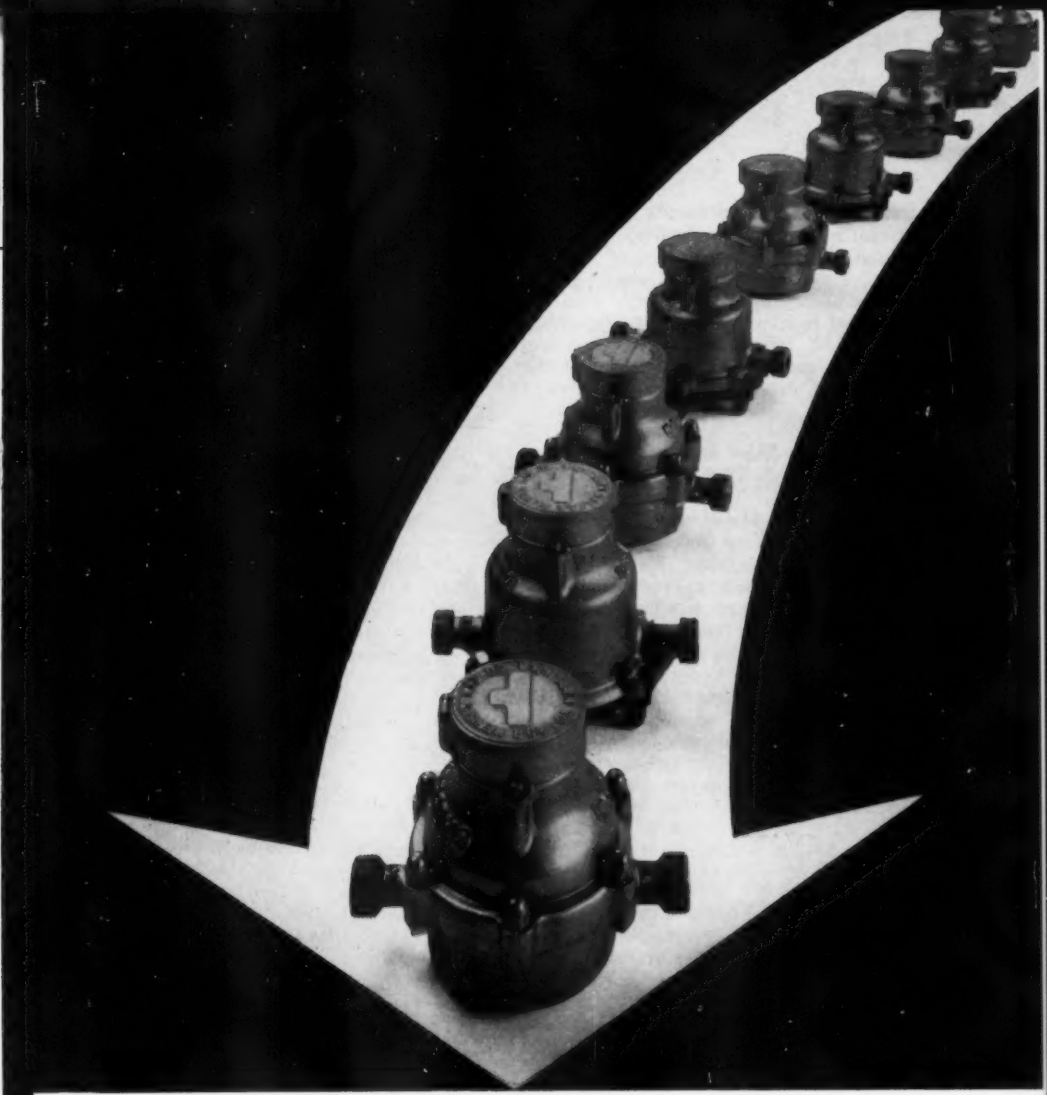
The Bala Lake Scheme of the Dee and Clwyd River Board. Wat. & Wat. Eng. (Br.), **60**:331 ('56). Bala lake scheme of Dee and Clwyd River Board is described. New works have dual purpose of alleviating recurrent flooding in Dee Valley and of increasing water storage available in Bala lake for water undertakings drawing from this source. Water from river Tryweryn is diverted, against normal flow, via new channel, into Bala lake for storage, and new channels, weirs, control sluices and gaging station have been constructed on Dee and Tryweryn to control flooding further down Dee valley. Provision has been made to facilitate passage of migratory fish at sluices by construction of fish lock.—*WPA*

Water Resources in the Congo. A. CLERFAYT. Bul. Centre Belge et. Document. Eaux, **29**:186 ('55). Author describes characteristics of ground water, and waters obtained from rivers, springs, and wells in Belgian Congo. Values for color, turbidity, odor, suspended matter, pH value. org. matter, hardness, chem. content, and elec. cond. of these waters are given in tables. Advantages of using wells fed by horizontal, radiating drains, where subsoil is suitable, are discussed.—*WPA*

Water Resources in Belgium. M. LEGRAYE. Bul. Centre Belge et Document. Eaux, **29**: 148 ('55). Author outlines geological structure of Belgium, giving locations of water-bearing strata, which are shown on map, and principal towns that receive their water supply from them. River water and use of dams and artificial lakes are further examples of many sources of water in country. —*WPA*

Water and Waste Waters in Austria. J. KAR. Literaturber. Wasser, Abwasser, Luft & Boden, **5**:61 ('56). Account is given of geology and hydrology of Austria and of conditions of water supply and disposal of sewage and waste waters. Water works serve about 50% of pop. Most supplies are drawn from springs but in recent times bank-filtered ground water and surface water have been more extensively used. Plans for protection of water resources, formation of group water supplies, separate supplies for

(*Continued on page 76 P&R*)



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(*Continued from page 74 P&R*)

industries, and requirements of navigation, stream regulation, and flood control are discussed. Problems of disposal of waste waters are then considered. Damage has been caused mainly by waste waters from foundries and metal-working industries. Sewage from about 200,000 of pop. receives mech. treatment and sewage from about 50,000 receives biol. treatment also. Costs of improvements required are estd.—*WPA*

Dune Water Flow and Replenishment in the Catchment Area of the Amsterdam Water Supply. I. C. BIEMOND. J. Inst. Water Engrs., **11**:195 ('57). Since 1853, Amsterdam's water supply has been obtained from dunes along North Sea coast. This paper by director Amsterdam Water Supply Undertaking, describes development of supply, geology and hydrology of area and changes brought about by overdraft of available supply. Works now under construction will bring some 15 mgd of filtered Rhine R. water 33 mi. to dune catchment area where infiltration channels will be constructed to permit recharge of underground supply. This will create barrier against further salt water intrusion and also permit further purification of heavily pold. Rhine R. water. System is designed for expansion to 24–30 mgd of recharge water.—*PHEA*

Caracas Water Supply Lifted 3,125 Feet Over Divide. J. G. PIERETTI & E. C. COLE. Civil Eng., **26**:48 ('56). Caracas water supply is lifted 3,125 ft over 18 mi. of rugged, mountainous country. This is done against grades of over 50% in some places with 4 pumping stations. Each pumping station has 4 2-stage horizontal centrifugal pumps; each pump has rated capac. of 13,550 gpm against head of 833 ft. Pumps are driven by 3,500-hp synchronous motors—6,000 v at 1,500 rpm. Steel piping of 49.5-in. was used to carry water. Thickness of piping varied from 10 to 17 mm. Inside of pipe (after testing) was coated with bitumastic lining; outside of pipe was coated with mixt. of spun glass and asphalt. This system was completed within 18 mo. after contract signing. It is one part of 60-million dollar program for completing and extending Caracas water supply.—*PHEA*

Some Recent Solutions to Problems of Water Supply and Economy in the Netherlands. C. v. ROOYEN. Bul. Centre Belge et. Document. Eaux, **29**:176 ('55). Author describes methods used to supplement water supplies of The Hague, Amsterdam, Rotterdam, Zeeland S.A., and Enschede, in Netherlands. In Rotterdam capac. of river-water supply has been increased by using chem. treatment plant in addn. to existing biol. treatment in slow sand filtration plant. Effluents from both plants are mixed, giving total plant capac. of 70 million cu m per yr. Flow diagram of plant is given and also sketch of tank in which ferric chloride is produced. At Enschede, The Hague, and Amsterdam, and in southern Zeeland, groundwater supplies have been increased by artificial recharge with surface water from nearby rivers and canals, after purification. In southern Zeeland disused canal has been used to form reservoir to which water is pumped from across Belgian frontier. Sketch map of district is given, showing pumping station, reservoir, and treatment plant. To ensure supplies to meet future needs in western part of country, author recommends construction of large impounding reservoirs.—*WPA*

Water Supply in the Federal Republic of Germany, the Problems it Raises and the Efforts Made to Solve Them. KUMPF. Bul. Centre Belge et. Document. Eaux, **29**:182 ('55). Author outlines general position of water supply industry in Western Germany. Rising standards of living and large increase in pop., due to migration from central and eastern Germany have increased demand for water. To meet this demand, surface water must be used, incurring large expenditure on treatment plant. However, some economy has been achieved in steel industry by reuse of its process water, resulting in reduction of from 20 cu m to 5–6 cu m of water used to produce 1 ton of steel. It is hoped that similar economies will be possible in other industries. Large-scale regional planning of water supplies, and uniform laws throughout the Republic to conserve the water table and to protect surface water from pollution are recommended. A geological survey is being carried out to determine the ground-water resources. The international control of frontier water resources, such as lake Constance and the river Rhine is discussed.—*WPA*

Israel's Water Problem. Wat. & Wat. Eng. (Br.), **60**:436 ('56). To supply large quants. of water that Israel needs for irri-

(*Continued on page 78 P&R*)

Overall view shows dry well and discharge risers. Close-up (lower photo) shows a 30-inch Rotovalve equipped with electric motor-driven operators.

SMS-Rotovalves On Sewage Pump Discharge **GIVE ACCURATE THROTTLING**

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(Continued from page 76 P&R)

gation, particularly for development in Negev, and also for domestic and industrial use, all available sources must be used. In addition to water from wells, springs, streams, and flood water, water from river Jordan is essential to plan to supply 1,800 million cu m annually within next 10 yrs. National supply scheme will incorporate 3 types of projects: local irrigation systems drawing water from springs or wells; larger schemes which will include drainage of Huleh lake and swamps and irrigation of that area; irrigation of Beisan valley and Jordan valley south of lake Tiberias by water from lake; irrigation of coastal plain and Esdraelon valley with water from springs and wells in area and from river Kishon; and eastern and western Yarkon-Negev projects which will supply water to southern coastal plain and northern and western Negev by pipeline from river Yarkon; and finally, major Jordan-Negev* scheme which will connect and regulate other schemes. This major scheme will consist of canal from river Jordan at B'not Yaakov diverting avg. supply of 435 million cu m of water to hydroelectric station at Tabgha. Of this flow, 200 million cu m will pass directly to reservoir at Wadi Tufah and remainder will be used to produce power, passing into lake Tiberias, from where it can be pumped back into canal. From Wadi Tufah water will be pumped to existing storage reservoir with capac. of 7 million cu m in Beit Netofa valley and thence will flow through main conduit to reservoir at Faluja from which smaller pipelines will pass into Negev. Lake Tiberias will be used as main storage reservoir for system, water from saline springs on western shore being diverted to river bed below lake outlet. Other storage reservoirs are planned for southern end of pipeline. Districts normally obtaining water from wells will be supplied from this system in times of above avg. flow, resting wells and allowing water table to recover. Scheme has been designed to allow cooperation with neighboring states in regional use of water from river Jordan.—*WPA*

A Rural Water Supply Scheme. Civ. Eng. (London), **52**:164 ('57). 2 reservoirs and treatment plant have been constructed at Penycae by Wrexham and East Denbighshire Water Company, to serve rural areas of Rhos and Ruabon. Plant has capac. of 1 mgd, and treatment comprises coagulation with alumina ferric, filtration through pressure sand filters, adjustment of pH value with lime, and chlorination.—*WPA*

Torquay Corporation Waterworks Undertaking. A review. 1856–1956. J. Brit. Water Works Assoc., **38**:360 ('56). Torquay Waterworks Act, 1856, vested in Torquay Local Board of Health sole responsibility for supply of water to Torquay and neighboring districts, and historical outline is presented of continued development and improvement of Water Undertaking's resources and treatment plant, distr. network and service reservoirs necessary to meet increasing demands and extension of area of supply in ensuing 100 yrs. Today's supply is obtained from 4 impounding reservoirs with total capac. of 848 mil gal in Kennick, Trenchford and South Teign river valleys. Filtration plant at Tottiford has been expanded since its installation in 1912 and now consists of 32 pressure filters capable of yielding 4–7 mgd. Work is proceeding on installation of new automatically controlled chem. treatment plant at Tottiford works. In 1866 severe corrosion and nodular encrustation of cast-iron mains caused by soft acid water, was removed by use of, for first time it is claimed, automatic pressure-pipe scraper; cast-iron trunk mains are now scraped annually. Noncorrosive asbestos-cement pipes have been used in preference to iron pipes since 1932.—*WPA*

CHEMICAL FEEDING, CONDITIONING AND SEDIMENTATION

Coagulation and Sedimentation. J. M. DallaValle. Proc. Am. Soc. Civ. Engrs., No. HY4, p. 1052 ('56). Math. discussion of coagulation and of sedimentation.—*CA*

Principles of Flocculation Related to Water Treatment. P. D. Haney. Proc. Am. Soc. Civ. Engrs., No. HY4, p. 1036 ('56). Mechanisms of, and factors affecting, coagulation and flocculation are quantitatively discussed.—*CA*

Hypochlorination for Slime Control. J. D. Springs. Power, **101**:102 ('57). Inter-

(Continued on page 80 P&R)

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(Continued from page 78 P&R)

mittent use of hypochlorite as against continuous use of Cl was less expensive, yet produced similar results.—*CA*

Treatment of Water by the Aid of Coagulants. I. A. Driz. Spirtovaya Prom. (USSR), **22**:27 ('56). General discussion of reactions $Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 6CO_2$, $2FeCl_3 + 3Ca(HCO_3)_2 = 2Fe(OH)_3 + 3CaCl_2 + 6CO_2$ for treatment of H_2O. Second reaction is preferred for practical applications.—*CA*

New Flocculants Yield Real Benefits. Chem. Eng., **64**:162 ('57). Advantages of new types of org. coagulants are discussed, and their performance is compared with inorg. coagulants and older types of org. coagulants. Choice of org. coagulant, method of application, and costs, are considered briefly. Most widely used so far is Separan 2610.—*WPA*

Experiments on the Electrolytic Chlorination of Water. F. W. Brauss. Arch. Hyg. u. Bakteriol., **139**:132 ('55). Electrolytic chlorination might be used to treat strongly saline water for certain types of pools. Lab. expts. were made to det. amt. of available Cl produced by different combinations and sizes of electrodes immersed for 3 min in water contg. 0.1% NaCl with a current of 1.1 amp. It was found that bubbles of Cl produced were small and well distributed, and it is concluded that this method could be used to produce min. doses of Cl, and thus reduce risk of irritation of respiratory tract.—*CA*

Physicochemical Study of Calcareous Sedimentation. A. Riviere & S. Vernhet. Compt. Rend. (Fr.), **244**:2080 ('57). Littoral pond waters of Languedoc in summer have higher pH than sea water, sometimes as high as pH 9, but no unusual activity by photosynthesis. Elevated pH and high alk. reserve (Ca and Mg carbonates in soln.) of these low-salinity waters are explained by law of mass action in terms of $CaCO_3 + CO_2 + H_2O \leftrightarrows Ca(HCO_3)_2$ and $Ca(HCO_3)_2 + 2H_2O \leftrightarrows 2H_2CO_3 + Ca^{++} + 2OH^-$. It explains absence of carbonate pptn. from sea water by anaerobic reduction of sulfates where preexisting supply of limestone is lacking. It also elucidates certain problems in oceanography. That alk. reserve of fresh waters can become higher than that of sea points up significant role of river waters in process of limestone sedimentation.—*CA*

Production and Handling of Lime Slurry for Use in Chemical Applications. L. J. Minnick & C. A. Danforth. Ind. Wastes, **1**:248 ('56). Lime-handling system and method of formation of high concn. lime slurries for treatment of acid wastes is described. Advantages of using hydrated lime over quicklime in some acid waste treatment applications are enumerated: higher dispersion of solid particles, improved reaction rates, higher combining efficiency. High-solids concn. lime slurry is obtained from truck contg. dry bulk lime by means of slurry eductor which may be coupled to low-pressure water supply. At optimum water pressure of 25–30 psig, slurry may be obtained contg. avg. of 30% solids by wt. Concns. as high as 50% solids by wt. may be obtained by recycling some of slurry and adding it to water used in discharging truck. Concns. as high as 50% conserve storage tank space and yet produce pumpable mix that shows low tendency to settle. Graph is presented from which size of lime slurry storage tank can be detd. for different quants. of lime. Diagram of waste treatment plant arrangement is given. Operation of plant is described.—*PHEA*

The Behavior of Humic Substances in Water. Humic Acid Flocculation in Peat-Bog Waters. II. Action of Electrolytes. G. v. Beneden. Bul. Centre Belge Etude et Document. Eaux (Liege), **33**:173 ('56). This work, continuing some previous research on subject, establishes that influence of sol. Fe^{++} salts on pptn. of humic substances in presence of acid is not result of simple adsorption. Evidence shows that there is very likely reaction taking place between Fe^{++} and specific substances present in peat. Certain definite proportions are necessary for complete reaction and so that none of these reactants appear in filtrate. So-called "complexed" ion thus exerts flocculating action on humic substances by giving a ppt. with them in slightly acid soln. (pH 6.0), and appears to be in reality "complexing" agent. These expts. were effected by using peat extract in which humic material was about 10 times as concd. as it normally is in peat-bog water. In such waters, above reactions could not be evidenced, most likely due to lower concn. of reactants.—*CA*

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Making a large cut with the Mueller C-1 Drilling Machine powered by the portable H-602 Gasoline Engine Drive Unit.

The Mueller CC Drilling Machine offers basically the same features as the C-1, but is hand-operated.

Install inserting valves, connect branch mains and make other cuts through cast iron, steel and asbestos-cement pipe with the power-driven Mueller C-1 Drilling Machine.

Automatic or manual feed gives the operator positive control over the complete 25" boring bar travel. A feed indicator shows the actual depth of the cut at any time during the drilling operation. Cuts can be made under pressures to 500 p.s.i. at 100° F. or under temperatures to 500° F. at 250 p.s.i.

H-602 Gasoline Engine Drive Unit

Both the H-600 Air Motor and the H-602 Gasoline Engine Drive Units are specifically matched to the C-1 Drilling Machine for maximum performance. The air motor unit will advance the boring bar 1" in about 8 minutes. The gasoline engine unit is a trifle slower but is more powerful and gives more positive results when making large cuts through steel pipe.

H-600 Air Motor Drive Unit

Compare the many advantages of the power-driven Mueller C-1 Drilling Machine with your present method of making cuts. Ask your Mueller Representative for complete information and costs.

Since 1857

MUELLER CO. 100 YEAR SERVING AMERICA'S WATERWORKS QUALITY

MUELLER CO.
DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles, in Canada: Mueller, Limited, Sarnia, Ontario

(Continued from page 56 P&R)

Cochrane Water Conditioning Ltd., a subsidiary of Cochrane Corp., Philadelphia, has established permanent headquarters in its new building at 1355 Martin Grove Rd., Toronto, Ont. The company also maintains offices in Montreal, Que., and Winnepeg, Man.

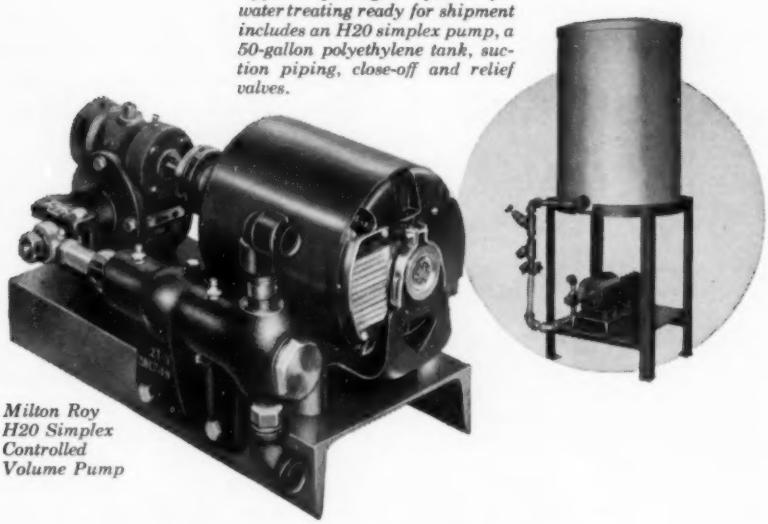
A toast—with water, of course—to $8,000,000 in Shreveport, La., water and sewerage system improvements was given at the recent public inspection and open house held by the water department. (The toasters in the photo below are, left to right, Thomas L. Amiss, superintendent of water and sewerage; R. L. Hyde, chief engineer at the Cross Lake treatment plant; and Ed Phelps, commissioner of public utilities.) Increased treatment capacity, new distribution lines, and a tie-in to a new source of supply, northwest Louisiana's Caddo Lake, are included in the $5,000,000 worth of water system improvements now nearing completion.

The rigors of Army life reached an almost unbearable point last summer at the Fort Bragg officers club, when the * water fountain would produce nothing but seltzer water. It isn't clear whether the "superior officers" whose thirsts went unquenched for the 4-hr duration of the emergency use plain water "with" or as a chaser, but, either way, we can certainly appreciate their distress. Fortunately, there were no

* Pronounced "blankety blank."

(Continued on page 84 P&R)

Typical packaged system for water treating ready for shipment includes an H20 simplex pump, a 50-gallon polyethylene tank, suction piping, close-off and relief valves.



Milton Roy H20 Simplex Controlled Volume Pump

Controlled Volume Pumps meter chemical solutions accurately

You can depend on Milton Roy H20® Controlled Volume Pumps to meter your boiler-water treatment chemicals accurately, in addition to other mildly corrosive and non-corrosive liquids.

High metering accuracy, long service life, minimum maintenance, availability from stock, and low cost are all advantages of H20 pumps. They embody quality design features usually found only in higher priced pumps, including: self-aligning bearings . . . self-adjusting packing . . . double ball checks on suction and discharge . . . cartridge-type, easily replaceable valves . . . standard continuous flushing connections.

For your water treating jobs, Milton Roy Controlled Volume Pumps can provide the logical, economical answer to chemical metering as well as accurate flow control. Write for Bulletin 557.

Milton Roy Company, 1300 East Mermaid Lane, Philadelphia 18, Pa. *Engineering Representatives throughout the world.*

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CHEMICAL INSTRUMENTATION SYSTEMS

CONTROLLED VOLUME PUMPS • QUANTICHEM ANALYZERS
CHEMICAL FEED SYSTEMS • ANDERS AIR AND GAS DRYERS

1940–1955

CUMULATIVE INDEX TO THE JOURNAL

These features make the new 16-year Cumulative Index (clothbound, 192 pp.) a time-saving, easy-to-use guide to JOURNAL AWWA for 1940–1955:

● **topic index**—titles of all articles on a particular subject are listed together under the appropriate heading, with cross references to related topics.

● **geographic index**—lists names of places and areas dealt with by articles in detail.

● **author index**—provides a key to all articles by every author during the 16-year period covered.

● **other reference aids**—complete topical outline, alphabetical list of subjects, table of text page numbers for each issue.

List price, $4.50

Price to members sending cash with order, $3.60.

AMERICAN WATER WORKS ASSOCIATION

2 Park Ave., New York 16, N. Y.

(*Continued from page 82 P&R*)

major casualties—not even the repairman, who had to explain that the fault lay in the new soft-drink dispenser, which had built up too much pressure and backed carbonation into the fountain. We haven't been able to find out whether those * soft drinks have since been declared out of bounds, but it is good to know that plain water is really appreciated.

Not a Toni, but a Len is the distinction that one twin we know boasts of, and as the twin is Minneapolis's, it becomes obvious that the Len is that erstwhile teacher and football coach named Thompson who, having caught the water bug on a summer job, joined the St. Paul Water Dept. in 1912 as a $50-a-month draftsman and, with a short break for military service during World War I, has been a part of the staff ever since, becoming General Superintendent and Engineer in 1929 and General Manager in 1945. What brings this bit of history now is the fact that, although 45th anniversaries are usually as remembered as second cousins' birthdays, Len's 45th brought Commissioner of Utilities Milt Rosen and the whole water department staff around to congratulate him and to ply him with cigars, tobacco, and all the tools of the smoking trade. And more welcome yet, to give him the time to do the necessary smoking, the city succeeded in obtaining the services of Cliff Hamblin, former superintendent of the Mason City, Iowa, water department, to work with Len. Now, with a present AWWA director from a past state and an ex-twice-director and former president of AWWA taking care of its water supply, the saintly twin doesn't need a Toni.

* Still pronounced "blankety blank."

(*Continued on page 86 P&R*)

BOTTLE TIGHT JOINTS IN ALL

Strength is essential for an efficient water pipeline—steel pipe has it.
Flexibility is just as necessary—steel pipe has it.
Economy of installation is certainly desirable—steel pipe has it.
But what makes these assets doubly valuable to you—is the fact that
steel pipe can give you bottle tight joints.
When you use Steel Pipe your joint problem is
solved—steel water pipe assures bottle tight
joints for the life of your line. That's why
you're so smart to specify steel pipe!

"WHEREVER WATER FLOWS—STEEL PIPES IT BEST"

STEEL PLATE FABRICATORS ASSOCIATION

79 W. MONROE ST., CHICAGO 3, ILL.

(Continued from page 84 P&R)

Indianans shouldn't have any difficulty remembering the street address of the Asuncion, Paraguay, water works: Avenue Senator Homer E. Capehart. The nomenclature is in recognition of the senator's active interest in connection with the Export-Import Bank loan that made the water works construction possible.

APHA has initiated a long-range technical development program concentrating on such fields as radiological health, accident prevention, environmental health, and public health administration. AWWA's B. A. Poole, of Indiana, is a member of the board coordinating the program, and Dwight F. Metzler, of Kansas, is chairman of the technical committee on environmental health.

Herman Gruher has been appointed to the newly created position of market research and sales training manager for Keasbey & Mattison Co., Ambler, Pa. He was formerly with Multiwall Packaging Div. of St. Regis Paper Co., New York, where he was engaged in similar work.

Richard Ankener, retired deputy commissioner of the New York City Dept. of Water Supply, Gas & Electricity, died Sep. 9, 1957. A graduate of the Cooper Union School of Engineering, he joined the department in

(Continued on page 88 P&R)

IRON REMOVAL & WATER SOFTENING

During 1956 we built a large number of durable and efficient low cost water treating plants for the removal of iron, manganese, hardness and other undesirable impurities. These plants operate *automatically,* require very little space and are unusually inexpensive to operate and maintain.

Full Particulars on Request

H&T SERVICE

HUNGERFORD & TERRY, INC.

CLAYTON 5, NEW JERSEY

Consulting Engineer L. W. Veigel

SPECIFIES

INERTOL® COATINGS

throughout new

2-MGD WATER WORKS,

Dickinson, North Dakota

Torex® Enamel, in Sea Green No. 304, protects submerged surfaces of filter beds against water and water treatment chemicals. Photograph shows E. A. Tschida, Plant Superintendent, checking filter valves.

SPECIFICATIONS FOR TOREX ENAMEL:
A glossy, chlorinated natural rubber-base coating . . . fade-resistant. For submerged surfaces of concrete and steel in water works.

Concrete Surfaces:
Colors: Color Chart 560. **No. of coats:** One TOREX Enamel over one TOREX Undercoater. **Coverage:** 250 sq. ft. per gal. per coat. **Approx. mil thickness per coat:** 1.0. **Drying time:** 24 hours between coats; 7 days before submerging. **Primer:** TOREX Undercoater. **Thinner:** Inertol Thinner 2000. **Application:** Apply to etched concrete. **Brushing:** As furnished. **Spraying:** Add sufficient Inertol Thinner 2000 (10 to 50%). *(Write for* TOREX *steel-surface painting specifications.)*

● In addition to TOREX ENAMEL, Consulting Engineer Veigel specified: colorful RAMUC® UTILITY ENAMEL, chlorinated natural rubber-base, for nonsubmerged masonry; GLAMORTEX® ENAMEL, mar-resistant alkyd, for nonsubmerged metal to be painted in color; INERTOL No. 49 Thick, long-wearing asphaltic coating, for submerged metal where black bituminous paint is suitable.

Inertol coatings have met the requirements of hardness, elasticity and chemical inertness in water works throughout the country. That's why Mr. Veigel chose them for the city of Dickinson, a growing farm and mining community with a prosperous future.

Buy Inertol paints direct from the manufacturer. Shipment within three days from our plant, or from nearby warehouse stocks. For full information about Inertol coatings, write today for free "Painting Guide."

Ask about Rustarmor,® Inertol's new hygroscopically controlled rust-neutralizing paint.

INERTOL CO., INC.

A COMPLETE LINE OF QUALITY COATINGS FOR SEWAGE PLANTS & WATER WORKS

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Visit us at the American Water Works Association Convention—Booth 405

Your call brings quick delivery from a Jones plant

CHLORINE service that's only a telephone away

Call us for Chlorine as you need it, and get safe, swift delivery—often in just a few hours.

You can eliminate the high cost and nuisance of storing large amounts of Chlorine by ordering it as you use it. There are seven **Jones** Company plants conveniently located across the U.S. ready to supply you—whether you want 16-, 105-, 150-lb. cylinders or 1-ton tanks.

Quality of **Jones** Chlorine is unexcelled—meets all rigid government specifications.

Learn yourself why **Jones** supplies more municipalities in the U.S. than any other Chlorine packer. We will be glad to review *your* contract requirements at any time. Call or write for information.

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Tele: Franklin 6-7790, 6-1922

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Tele: Elgin 4-5503, 6-3321

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14400 N.E. 20th Lane
Tele: North Dade 6-1461 6-1462

RIVERVIEW, WYANDOTTE, MICH.
18000 Payne Ave.
Tele: Avenue 3-0676

JOHN WILEY JONES CO.

(*Continued from page 86 P&R*)

1900 as a chainman and rodman. Later he became an assistant engineer, a position he held until his appointment as deputy commissioner in 1941. He retired in 1946 to enter private consulting practice.

A Life Member of AWWA (joined in 1922), Mr. Ankener also belonged to the Municipal Engineers Assn. and the Brooklyn Engineers Society.

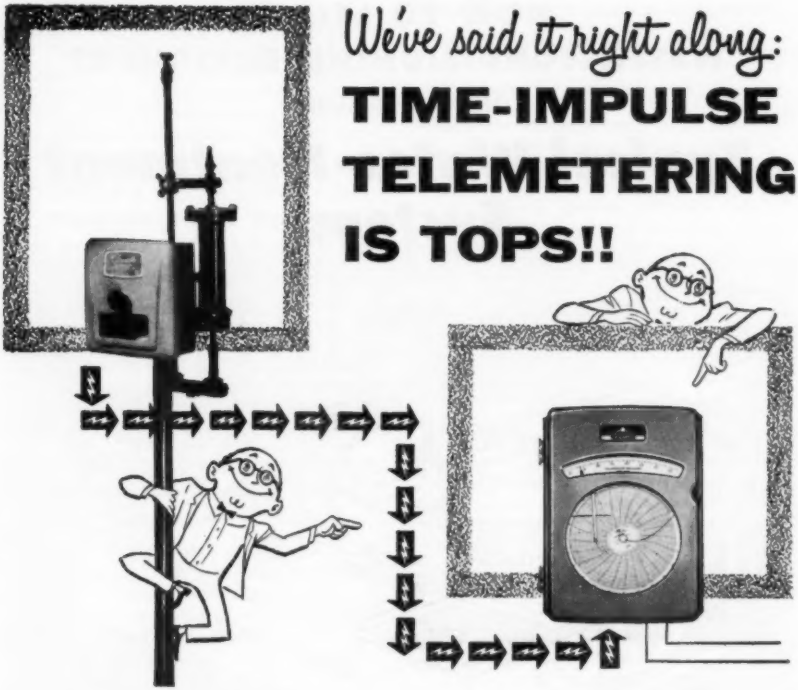
Charles H. Beebe, partner in the engineering firm of Harwood Beebe Co., Spartanburg, S.C., was killed Jun. 23, 1957, when a small private plane he was flying crashed near Union, S.C. His college career interrupted by service with the US Air Force, Mr. Beebe received a B.S. in civil engineering from The Citadel in 1948. Since then he had been an active employee and partner in Harwood Beebe Co.

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

HYDRAULIC ENGINEER: 14 years experience in pipelines, pumping, water resources. Desires to locate in Washington, D.C., as representative of water supply equipment manufacturer. Box 111, Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.



We've said it right along:

TIME-IMPULSE TELEMETERING IS TOPS!!

...AND YOU'VE SAID IT TOO...WITH YOUR ORDERS!!

In Builders Chronoflo Telemetering Systems: The transmitting and receiving reactions depend only upon the *positively* controlled duration of regular electric circuit closures and *nothing* more.

*The Telemeter is a pure, *positive-action* positioning system.

- It *does not* have to *translate* units of electric measurement into terms of rate of flow or other factors measured.
- It requires *no* relatively delicate electric components.
- It *doesn't employ* a series of contact rods "shorted out" by step-by-step action of rising mercury.
- It is *not affected* by normally encountered induced voltages.
- Receiver *accuracy not affected* by room temperature, line pressure, duration of "down time", and similar factors.

*The Chronoflo Receiver is *not* inferentially positioned except with respect to time duration of the Transmitter signals.

These are *only a few* reasons why time-impulse telemetering is "Tops". Let the company which pioneered this system over 25 years ago and has the experience gained in engineering thousands of installations give you complete proof of its dependability and accuracy.

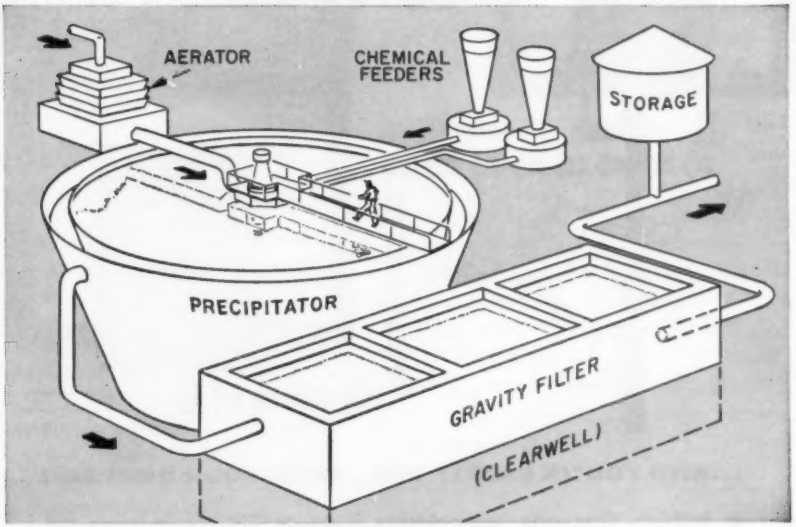
Request Bulletin 230-H4A. Write Builders-Providence, Inc., 365 Harris Ave., Providence 1, R. I.

BUILDERS-PROVIDENCE
DIVISION OF
B-I-F INDUSTRIES BIF METERS FEEDERS CONTROLS

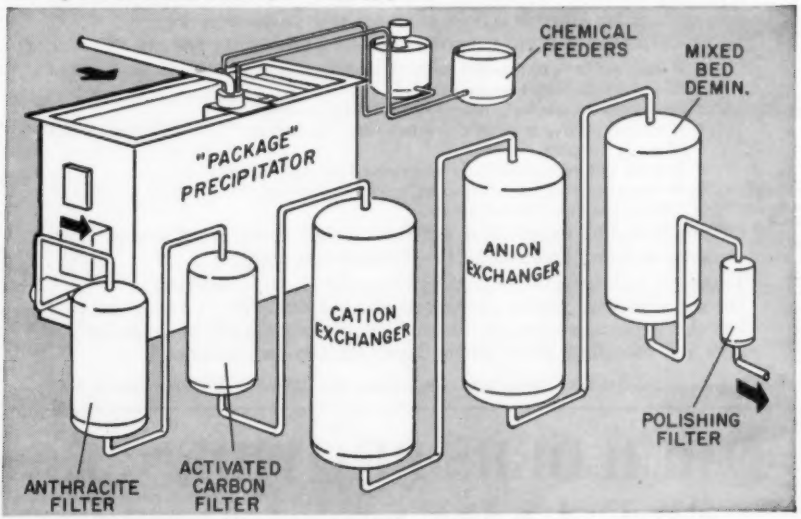
HOW TO SELECT WATER-CONDITIONING EQUIPMENT

(NO. 6 OF A SERIES)

Typical Water-treatment Systems



Treating a well water for a municipal water supply



Treating a process water used in manufacturing electronic components

These factors are involved in selecting types and sizes of equipment for a specific use: Analysis of the raw water, volume and quality of water required, initial and operating cost of equipment, rate of amortization and future expansion possibilities. Typical systems illustrating widely varying requirements:

Treating a well water for a municipal water supply

(or as pretreatment for demineralizing)

Aerator reduces CO_2 . . . to lower acidity. It also reduces taste and odor and oxidizes any dissolved iron or manganese. **Precipitator,** depending on the chemicals used, removes turbidity, color, hardness and oxidized iron and manganese. **Gravity filter** removes remaining traces of turbidity from Precipitator effluent.

Treating a process water used in manufacturing electronic components

"Package" Precipitator removes the bulk of the turbidity, hardness and iron. **Anthracite filter** removes remaining suspended matter from precipitator effluent. **Activated carbon filter** removes color and absorbs dissolved organic matter. **Demineralizer** (cation, anion and mixed-bed units) reduces dissolved solids to a very low, guaranteed maximum. **Polishing filter** removes traces of suspended matter from demineralizer effluent.

Treating water for a steam boiler

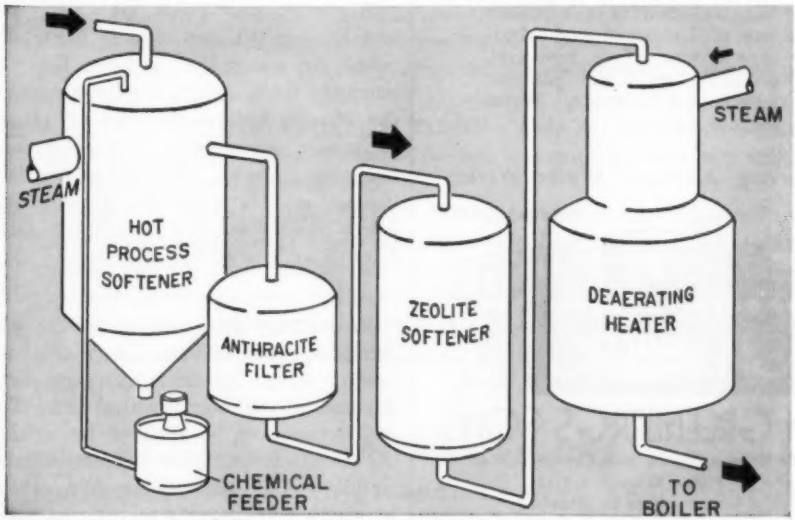
(For high-pressure-boiler feedwater treatment, see "9 ways to demineralize water by ion exchange".)

Hot-process softener reduces hardness to a few grains per gallon. It also reduces silica. **Anthracite filter** removes remaining turbidity from the effluent of the hot-process softener. **Zeolite softener** may be added where zero hardness is required. **Deaerating heater** removes oxygen to prevent corrosion.

For general recommendations on any type of water problem or equipment for its correction, write The Permutit Company, Dept. JA-11, 50 West 44th St., New York 36, N. Y. or Permutit Company of Canada, Ltd., Toronto 1, Ont.

NOTE: Reprints of this series of advertisements, "How to Select Water-Conditioning Equipment," are recommended as a handy "short course" for students and engineers. A set of reprints will be sent free, on request.

PERMUTIT®
rhymes with "compute it"
A DIVISION OF PFAUDLER PERMUTIT INC.
Water Conditioning
Ion Exchange • Industrial Waste Treatment



Treating water for a steam boiler

FIRE HYDRANTS

No. 74 & No. 76 California Type Wet Barrel Double Hydrant (for non-freezing weather). INDEPENDENT valves for each outlet; integral curved deflector head; full 6¼" waterway through hydrant body. Greenberg "Cascade" Dry Barrel hydrants are available for freezing climates.

We manufacture a complete line of Industrial and Maritime bronze valves, hydrants, plumbing specialties, plaques, letters and hardware. Write for our catalog.

Serving American Water Works

Founded 1854

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765 Folsom Street, San Francisco, Calif.
Phone Exbrook 2-3143
—with offices in principal cities of the United States.

Service Lines

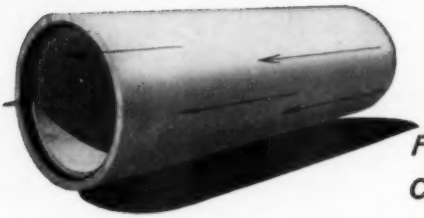
Demineralizers, their design, application, and operation, are the subject of an illustrated 8-page technical bulletin, issued by L A Water Softener Co. Copies may be obtained by requesting Bul. No. 108-A from the company at 1007 Air Way, Glendale, Calif.

Valve lubrication and maintenance is simplified by a 19 × 24-in., three-color chart. Made of heavy paper with metal edges, suitable for display on office and shop walls, the chart gives detailed information on four types of Rockwell-Nordstrom valves. It may be obtained by writing the Meter & Valve Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

A maintenance guide for its D7, D8, and D9 tractors has recently been published by Caterpillar Tractor Co. In narrative form, with full-color drawings, the 24-page booklet discusses all phases of proper maintenance, operation, and servicing. Copies, available in five languages, may be obtained by requesting Form 32395 from the Advertising Div., Caterpillar Tractor Co., Peoria, Ill.

Emergency cut-in valves are the subject of a 4-page bulletin, No. W-14, containing schematic drawings, parts lists, dimensions, and other technical data. The publication may be obtained by writing the manufacturer, Golden-Anderson Valve Specialty Co., 1221 Ridge Ave., Pittsburgh 33, Pa.

SMOOTH FLOW KEEPS COSTS LOW!



YOUR CITY SAVES ON MAINTENANCE COSTS FOR YEARS TO COME WITH CONCRETE PRESSURE PIPE!

Because of its great resistance to corrosion and tuberculation, dependable Concrete Pressure Pipe gives your city extra years of trouble-free service, gives impressive dollar savings on maintenance costs throughout its unusually long life span.

You save money for your city—from the trench to the pump—when you choose Concrete Pressure Pipe, with easy-fitting Rubber Gasket Joints. Specify it and get these "4 big savings" built into every piece of low-cost, long-lasting Concrete Pressure Pipe.

1. YOU SAVE ON FIRST COSTS—The variety of designs available in Concrete Pressure Pipe makes it possible to choose the most economical design which will serve with maximum efficiency under the specified operating conditions required of the line.
2. YOU SAVE ON INSTALLATION COSTS—With Rubber Gasket Joints, there's no caulking, bolting or welding needed. You can have minimum width trenches and immediate backfilling.
3. YOU SAVE ON MAINTENANCE COSTS—Durable Concrete Pressure Pipe has an experience record of almost complete freedom from corrosion and tuberculation. Elastic design virtually eliminates possibility of bursting—even under conditions of extreme surge and water hammer.
4. YOU SAVE ON OPERATING COSTS—Freedom from tuberculation insures a high sustained carrying capacity. No spiralling pumping costs and no reduced pressures.

In the main—the trend is to concrete!

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

228 North LaSalle Street • Chicago 1, Illinois

Section Meetings

Michigan Section: The Michigan Section held its nineteenth annual meeting in Detroit at the Detroit-Leland Hotel Sep. 25–27, 1957. The Motor City proved to be a very congenial host and had much to offer in the way of entertainment and water works expansion and planning. A record attendance of 427, including 86 ladies, indicated the interest the membership had in visiting Detroit and in the information provided on the technical sessions. [A list of papers and authors will appear in the December issue.]

The clever wit of Chairman Walter E. Smith and Toastmaster F. W. "Duke" Du Bois contributed toward a very enjoyable annual banquet on Thursday, Sep. 26. Greetings were presented by Albert E. Heustis, commissioner, Michigan Dept. of Health, and by President Merryfield. The banquet speaker, "Sonny" Eliot, brought much humor to his subject, "Weather and Water." Harry H. Caswell was nominated to receive the George Warren Fuller Award after many years of faithful service to his community and the Michigan Section. Thirty-three members received the Edward Dunbar Rich Service Award for 25 years of meritorious and faithful service in providing and maintaining a safe and adequate water supply.

The manufacturers' representatives and WSWMA again proved to be very gracious hosts at a smoker on Wednesday night and a cocktail hour on Thursday night preceding the banquet, as well as providing refreshments at the dance after the banquet.

T. L. VANDER VELDE
Secretary-Treasurer

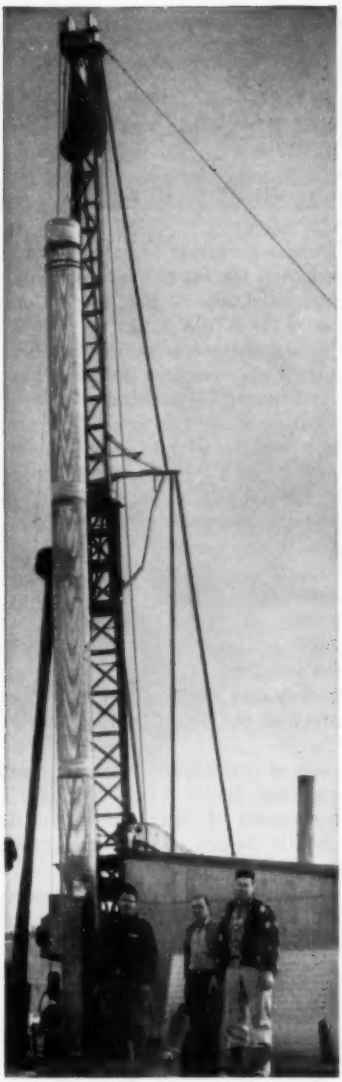
North Central Section: The North Central Section held its 41st annual meeting in Fargo, N.D., Sep. 25–27, 1957, jointly with the North Dakota Water & Sewage Works Conference. The program and all activities were carefully worked out well in advance by joint committees. The result was a most successful meeting, highly profitable to the membership of both groups.

Program papers were exceptionally timely and well prepared. A tribute to both papers and speakers was the size and attentiveness of the audiences at all sessions. [A list of papers and authors will appear in the December issue.]

The convention was officially welcomed at a special luncheon held Wednesday noon. A smorgasbord given by the Area Municipal Contractors Wednesday evening, Sep. 25, afforded an excellent opportunity for meeting of old friends. Thursday noon the annual luncheon and get-together of all past chairmen was held, with the present chairman, H. H. Behlmer, and AWWA Vice-President Finch as guests. The Annual Banquet, presentation of awards, and an evening of entertainment took place Thursday. William Yegen of Bismarck, N.D., was officially presented with his Life Membership Certificate; George J. Schroepfer was nominated for the Fuller Award; Nels F. Haagenson was given the Finch Award; and H. H. Behlmer was presented with the past-chairman pin.

At the business meeting on Friday, the following officers were elected: chairman —M. D. Lubratovich, Duluth, Minn.; vice-chairman—A. T. Hanson, Sioux

(*Continued on page 96 P&R*)



Johnson Well Screen of Everdur being lowered into the new 4-mgd well at Plymouth, Mich.

Big screen of EVERDUR serves new 4,000,000-gallon well in Plymouth, Mich.

In developing a new source of water to meet growing community needs, Plymouth, Mich., more than doubled the capacity of its water system with a single well capable of providing 4,032,000 gallons per day.

The new well is 110 feet deep, has an 18-inch casing, and a Johnson Everdur Well Screen 16¼" in diameter by 32', 1½" long. Edward E. Johnson, Inc., St. Paul, Minn., fabricates tough, corrosion-resistant well screens from specially shaped Everdur wire and rod by a unique automatic welding method. Johnson welded Everdur screens have proved their durability by years of service in large-capacity wells.

• **Everdur* resists corrosion.** Sewage-treatment and waterworks equipment of Everdur has been in service without replacement for 20 years and longer.

• **Everdur is tough.** Everdur also possesses high mechanical strength and resistance to wear and abrasion—so that engineers can design light-weight, wrought-metal equipment.

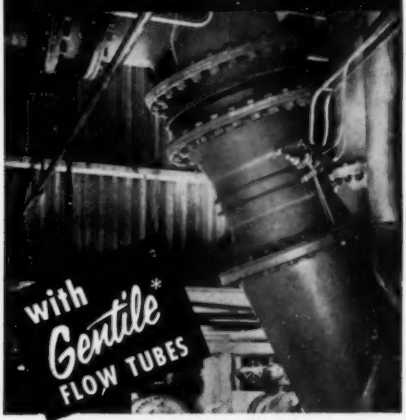
• **Everdur is readily fabricated.** Alloys are available for hot or cold working, welding, free machining, forging, and casting – and can be obtained in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

• **Write for Publication E-11,** "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

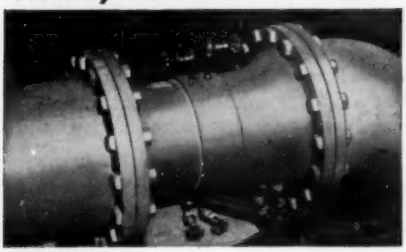
*Reg. U. S. Pat. Off. 57132

EVERDUR Anaconda's Family of Copper-Silicon Alloys
MADE BY THE AMERICAN BRASS COMPANY
STRONG • WORKABLE • WELDABLE • CORROSION-RESISTANT

PIPING LAYOUT IS SIMPLER



...they need so little room



*GEN-TIL-LY

Gentile Flow Tubes are short. They need only minimum straight runs entering and following, and can be installed at practically any accessible point where flow conditions are reasonably steady.

Flow Tubes are furnished with individual head capacity curves and for unusual piping arrangements, calibration curves for simulated conditions can be furnished.

Guaranteed Accuracy • Reproducibility Minimum Head Loss

FOSTER ENGINEERING COMPANY

835 LEHIGH AVENUE UNION, N. J.

AUTOMATIC VALVES • CONTROL VALVES
SAFETY VALVES • FLOW TUBES

Section Meetings

(*Continued from page 94 P&R*)

Falls, S.D.; trustee—William Yegen, Bismarck, N.D.; secretary-treasurer—Leonard N. Thompson, St. Paul, Minn.; and assistant secretary-treasurer—Carl Flack, St. Paul, Minn. The following resolution was adopted:

"*Whereas* a number of nuclear reactors are proposed for construction within the geographical limits of the North Central Section of the AWWA, and

"*Whereas* the use of radioactive fuel in such plants may create a potential hazard to natural waters now being used by our communities or planned for future use as a source of water supply, be it

"*Resolved* that the North Central Section of the AWWA establish a committee to study the problem, to acquaint themselves with the exhaustive studies being carried out by the various regulating agencies involved in the development of safeguards against radioactive contamination, and to present to these agencies recommendations for any further safeguards they may deem necessary to insure the safety of our water supplies; and be it further

"*Resolved* that copies of this resolution be forwarded to the AEC, the USPHS, the department of health in North Dakota, South Dakota, and Minnesota, and the Secretary of the AWWA."

A total attendance of 136 was reported, plus 41 ladies who enjoyed a luncheon and style show, a tour of the city of Fargo, and a visit to television station WDAY.

LEONARD N. THOMPSON
Secretary-Treasurer

Rocky Mountain Section: The 31st annual meeting of the Rocky Mountain Section was held at the La Fonda Hotel in Santa Fe, N.M., Sep. 24–25. The total registration was 152. The program committee, under the chairmanship of V. A. Vaseen, Denver, Colo., had arranged for a most informative and interesting meet-

(*Continued on page 98 P&R*)

Into the ground with ease, and for keeps

K&M ASBESTOS CEMENT PIPE

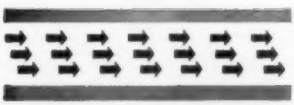
It's the modern pipe! Easy installation under any weather and ground conditions is just one of the advantages of K&M Asbestos-Cement Pipe. Other advantages: Permanently smooth non-tuberculating bore; non-corroding inner and outer surfaces; high resistance to electrolytic action; permanence of joint obtained quickly with exclusive K&M "Fluid-Tite"® Coupling.

K&M Pressure Pipe meets A.W.W.A., A.S.T.M. and U.S. Federal Specifications, and has Underwriters' Laboratories approval for all sizes (pipe and couplings) in Class 150.

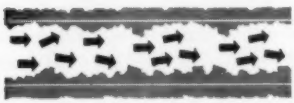
FOR GRAVITY SEWER SYSTEMS, K&M Sewer Pipe is the low-cost answer. "Fluid-Tite" Coupling makes permanent tight joint, prevents infiltration and root entrance.

FOR HOUSE-TO-SEWER CONNECTION, K&M Building Sewer Pipe and 2-Step couplings round out the K&M family of asbestos-cement pipe.

Get the whole story on the modern pipe from the K&M distributor.



After many years, K&M Pipe hasn't tuberculated, bore remains unchanged, and full flow continues.



Old-fashioned pipe tuberculates over the years, requires higher pumping pressure, frequent cleaning.

K-M BEST IN ASBESTOS

KEASBEY & MATTISON Company • Ambler, Pennsylvania

In Canada, it's ATLAS ASBESTOS CO., Ltd., 5600 Hochelaga St., Montreal, P. Q. for "CENTURY" Pipe and "FLUID-TITE" Couplings

Section Meetings

(Continued from page 96 P&R)

President Merryfield is shown with Rocky Mountain Section Director Turre (left) and Secretary Davis (right).

Indian dancers from Taos, N.M., entertain at Rocky Mountain Section annual banquet.

ing. [A list of technical papers presented will appear in the December issue.]

The meeting was opened with an address of welcome by Stanley J. Leland, director, New Mexico Health Dept. Chairman Barnes responded. At the business luncheon, the election of the following officers was announced: chairman—W. F. Turney, of W. F. Turney & Assoc., Santa Fe, N.M.; vice-chairman—Ray Nixon, of Colorado Springs, Colo., Water Dist.; secretary-treasurer—V. A. Vaseen, of Ripple & Howe, Denver; director—J. Orville Jones, water works superintendent, Pueblo, Colo. The following trustees were named to fill unexpired terms: Roel K. Stratton, superintendent of public utilities, Casper, Wyo., and S. J. Joseph, general manager, Northwest Utilities Co., Thornton, Colo.; the following trustees were named for 3-year terms: Simon F. Elliott, consulting engineer, Pueblo, Colo., and Robert P. Lowe, State Dept. of Public Health, Santa Fe, N.M.

The ladies were royally entertained under the chairmanship of Mrs. T. J. Eaton, ably assisted by the Missuses Turney, Caldwell, and Sanborn. A bus trip to the Atomic City, Los Alamos, with luncheon at the lodge and a tour of Indian villages, made an enjoyable day of Tuesday. On Wednesday, the ladies were entertained by the Santa Fe Garden Club, including a tour of the homes in Santa Fe and a marvelous tea.

The 31st Annual Banquet was held in the main dining room of the La Fonda Hotel with 151 in attendance. George Turre was presented with a Life Membership Certificate and received a standing ovation from his fellow members in recognition of his contributions to the Section. The entertainment consisted of dinner music by a very fine string orchestra from the Santa Fe High School and the Mexican Trio from the La Fonda Hotel, and was highlighted by the Indian Hoop Dancers of Taos.

The convention closed with the feeling that it was one of the most successful and enjoyable meetings in the Section's 31-year existence.

JACK W. DAVIS
Secretary-Treasurer

YOU WERE DOING THIS

WHEN THE FIRST HYDRO-TITE JOINTS WERE BEING POURED -

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For over 40 years HYDRO-TITE has been faithfully serving water works men everywhere. Self-caulking, self-sealing, easy-to-use. Costs about 1/5 as much as lead joints. Packed in 100 lb. moisture-proof bags.

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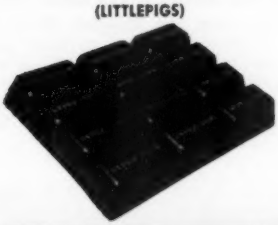

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The same dependable compound in solid form —packed in 50 lb. cartons—2 litters of pigs to the box—24 easy-to-handle Littlepigs. Easier to ship, handle and store.

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The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

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HYDRAULIC DEVELOPMENT CORPORATION

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How to select the best

Unless you check these 7 vital points, you won't be sure you're getting the controller that meets all your requirements

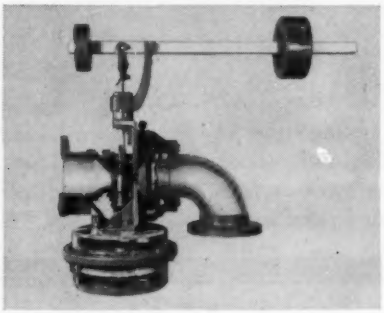
All controllers claim to fill your major requirements:

(1) hold flow at desired rate

(2) operate over wide ranges with low error

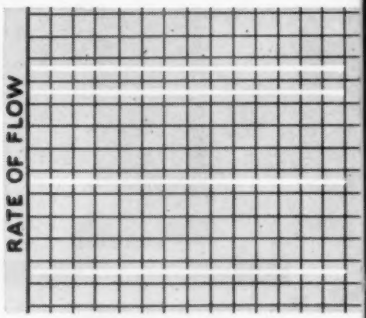
(3) maintain rate *automatically*

But the vital features outlined her determine whether or not you hav selected the one type that gives yo complete filter control.



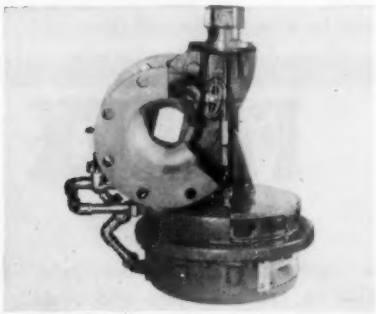
1. DIRECT ACTING

Some controllers require pneumatic or electric positioners to hold the desired rate. When power fails, filters run away. But all power can fail and the direct-acting Simplex Type S Controller (cutaway above) still keeps rate uniform.



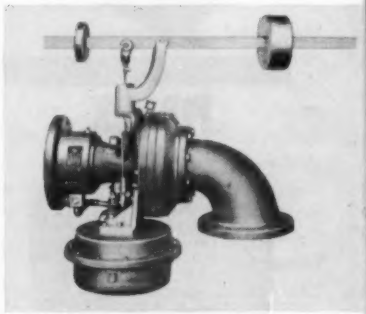
2. ACCURACY TO END POINT

Getting the longest filter run requires the most critical accuracy near the end point. That's where other controllers fail by fluctuating widely. For comparison, see above straight-line accuracy of Simplex Type S Controller.



3. PRESSURE LOSS

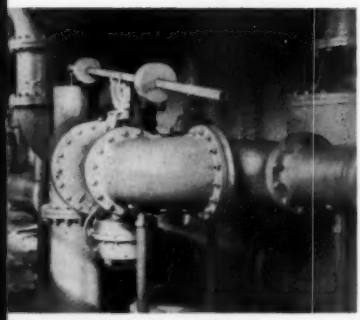
In other controllers, plates and seats obstruct flow. Above cutaway view of Simplex Controller shows absence of obstructions. Its patented guillotine valve provides the full-line opening that gives you low pressure-loss (under 1' at maximum flow)



4. TOTAL INSTALLED COST

Other controllers require expensive extras: straight pipe ahead of, or after, the unit; special pneumatic or electric positioners; additional wiring. In contrast, the Simplex Type S Controller is a complete, self-contained unit.

ilter rate controller

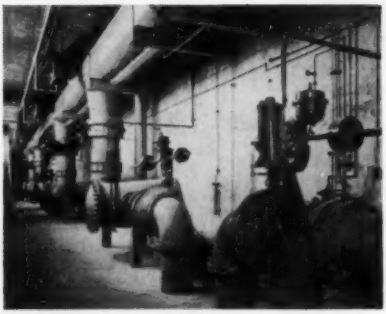


SPACE REQUIREMENTS

Controllers that require straight ipe runs waste valuable space, add reatly to plant cost. But, Simplex ype S Controllers are only 3 pipe iameters long, fit anywhere, hori-ontally or vertically, and eliminate idden cost of straight pipe runs.

PROVEN PERFORMANCE

To help you select the best control-er, check with the men who run ilter plants. Ask for their experi-nce. Map above shows a few Simplex installations. For others ear you—with up to 25 years' suc-essful performance, please write us.



6. MAINTENANCE COST

If used as controllers, ordinary valves require additional positioners—pneumatic or electric. Results: more moving parts; more wear; greater maintenance costs. Simplex Type S Controller is self-contained, operates without these extras, requires virtually no maintenance.

GET THE FACTS ON
SIMPLEX TYPE S CONTROLLERS, TODAY!
SEND FOR FREE TECHNICAL BULLETIN 900

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NEW MEMBERS

Applications received Sep. 1–30, 1957

Adams, George, Mgr., Hoosier Water Co., Inc., Mooresville, Ind. (Oct. '57) *MPD*

Ahles, Eldon Paul, Chief Oper., Water Filtration Plant, 26555 W. Huron Dr., Flat Rock, Mich. (Oct. '57) *MP*

Alexander, R. J.; *see* Oakland County (Mich.) Dept. of Public Works

Anderson, Burdine, Water Supt., Colville, Wash. (Oct. '57) *MRP*

Arfaras, Paul Nichols, Pres., Ridge Soft Water Service, 408—3rd St., S.W., Winter Haven, Fla. (Oct. '57)

Baker, John C., Salesman, Thompson Hayward Chem. Co., 909—2nd St., S., Minneapolis 15, Minn. (Oct. '57) *P*

Barning, David Lee, Vice-Pres., Barning Indus. Chems., Inc., 3109 Igleheart Ave., Evansville, Ind. (Oct. '57)

Beatty, J. P; *see* The K. Kessler Co., Inc.

Beeman, Edward R., Corrosion Engr., Harco Corp., Box 7026, Cleveland, Ohio (Oct. '57) *RD*

Bell, Ralph, Supt., Water Dept., Hartford City, Ind. (Oct. '57)

Bright, Walter C., Supt. of Utilities, Gas City, Ind. (Oct. '57)

Brown, Richard M., Owner, Culligan Soft Water Service, Box K-291, Holly Hill, Fla. (Oct. '57) *P*

Buercklin, Marion A., Field Cons., Curtis E. Montrey & Assoc., Box 6005, Tulsa, Okla. (Oct. '57) *P*

Buffalo Pound Water Admin. Bd., O. K. C. Mang, Plant Supt., City Engrs. Dept., Regina, Sask. (Corp. M. Oct. '57)

Burde, Frank R., San. Engr., Sales, Dravo Corp., 19 Rector St., New York, N.Y. (Oct. '57) *MP*

Butler, Ian, Project Engr., Proctor & Redfern, 11 Jordan St., Toronto, Ont. (Oct. '57)

Caldwell, W. E., Co., G. H. Duncan Jr., Sales Engr., 200 E. Brandeis Ave., Louisville 8, Ky. (Assoc. M. Oct. '57)

California Brass Mfg. Co., Marvin P. McCollum, Development & Research Engr., 1447 Naud St., Los Angeles 12, Calif. (Assoc. M. Oct. '57)

Callander, Dillman, Water Works Foreman, 302 N. Madson St., Nappanee, Ind. (Oct. '57)

Cameron, Munro McKinlay, Engr., DeLaval Steam Turbine Co., 227—7th Ave. E., Calgary, Alta. (Oct. '57) *D*

Carlson, Carl H., Partner, Flint Surveying & Eng., Co., 2320 Lippincott, Flint, Mich. (Oct. '57) *PD*

Clapsaddle, Jack L., Partner, Collins, Thompson, Willis & Clapsaddle, 105 Westwood Dr., Marshalltown, Iowa (Oct. '57) *RPD*

Clark, Thomas A., Chem. Engr., Minnesota Mining & Mfg. Co., Bldg. 207-1, 900 Bush Ave., St. Paul 6, Minn. (Oct. '57) *P*

Collier, Kine J., Jr., Salesman, Arkhola Sand & Gravel Co., 323 Merchant Bank Bldg., Fort Smith, Ark. (Oct. '57) *P*

Collins, Curtis J., Supt., Water Dept., 811 N. Range Line Rd., Carmel, Ind. (Oct. '57) *MPD*

Comeaux, Edric Joseph, Sales Engr., Rockwell Mfg. Co., Box 2126, Houston, Tex. (Oct. '57) *D*

Corbell, Otis Dean, Office Mgr., Water Dept., Court House Bldg., Fort Smith, Ark. (Oct. '57) *MD*

Cosby, Ira D., Salesman, P.B.&S. Chem Co., Henderson, Ky. (Oct. '57) *RPD*

Creston City Water Works, J. Bernard Russell, Mgr., 103 E. Montgomery St., Creston, Iowa (Munic. Sv. Sub. Oct. '57) *MPD*

Curry, Curtis C., Contractor, Curry Const. & Supply Co., 413 S. Washington St., Bloomington, Ind. (Oct. '57) *D*

Dahl, W. Robert, Civ. Engr., Centriline Corp., 140 Cedar St., New York 6, N.Y. (Oct. '57) *MD*

Dale, Jack E., Supt., Water Dept., Linton, Ind. (Oct. '57)

Davis, Louis Eugene, Asst. Supt., Water Works, Milford, N.J. (Oct. '57) *PD*

Dean, Joel Jackson, Engr., Dean Eng. Co., 11 N. Rosewood Dr., Albany, Ga. (Oct. '57) *PD*

Decker, Walter G., Supt., Munic. Utilities, Box 128, Lawrenceburg, Ind. (Oct. '57)

de Lisle, Kenneth R., Assoc. Engr., Benjamin L. Smith & Assocs., 11 N. Pearl St., Albany 7, N.Y. (Oct. '57)

Deo, Morris B., Sr. Assoc. Engr., Dept. of Water Supply, Detroit, Mich. (Oct. '57) *MPD*

Donze, Martin C.; *see* Philadelphia Gear Works, Inc.

Dooley, A. M., Sales Supervisor, Rockwell Mfg. Co., Box 2126, Houston, Tex. (Oct. '57)

Dow Chem. Co., The, Louisiana Div., T. E. Pounds, Gen. Supt., Power & Utilities Dept., Box 389, Baton Rouge, La. (Corp. M. Oct. '57) *RPD*

Drabenstot, Paul E., Dist. Supt., Water Dept., Huntington, Ind. (Oct. '57)

Dula, Harry L., Supt., Water Works Dist. 1, Box 521, Lafayette, La. (Oct. '57) *MPD*

Duncan, G. H., Jr.; *see* W. E. Caldwell Co.

Edwards, John Andrews, Cons. Engr., Box 10421, Raleigh, N.C. (Oct. '57) *PD*

Egby, Harvey, Supt., Water Dept., Berne, Ind. (Oct. '57) *MPD*

El-Naggar, A. Sami, Eng. Faculty, Univ. of Alexandria, Alexandria, Egypt (Jan. '57)

Emerick, Clarence E., Chief Lab. Tech., Water Dept., 1106—1st St., Lorain, Ohio (Oct. '57) *P*

Escondido, City of, Charles L. Larrick, City Engr., 100 Valley Blvd., Escondido, Calif. (Corp. M. Oct. '57) *MRPD*

Fensten, Harvey Charles, Civ. Engr., Ripple & Howe, Inc., 833—23rd St., Denver, Colo. (Oct. '57) *PD*

Ferguson, Lloyd W., Filter Plant Supt., Westminster, Colo. (Oct. '57) *RPD*

Ferraro, Louis, Foreman, Water Dept., 827 S. Bend Ave., South Bend, Ind. (Oct. '57)

Findley, William H.; *see* City of Sutherlin (Ore.)

Floeck, James H., Sales Engr., Burgess-Manning Co., 749 E. Park Ave., Libertyville, Ill. (Oct. '57) *P*

Folke, Gordon W., San. Engr., State Bd. of Health, Box 210, Jacksonville, Fla. (Oct. '57) *MRP*

Foulke, Charles I., Cons. Engr., Foulke, Crist & Brodie, Box 2005, San Bernardino, Calif. (Oct. '57) *MRPD*

Furman, Benjamin, Cons. Engr., 127 Beech St., Kearney, N.J. (Oct. '57) *M*

Garberville Water Co., Inc., Fred Hurlbutt, Secy.-Treas., Garberville, Calif. (Corp. M. Oct. '57)

Gillespie, J. Robert, Gen. Supervisor, Power & Fuel Engr., Geneva Works, U.S. Steel, Box 510, Provo, Utah (Oct. '57)

Govindaiah, Menta, Asst. Engr., Office of the Chief Engr., Hyderabad 4, South India (Oct. '57) *PD*

Grant, Joe Lee, Supt., Canal & Waterworks, Augusta, Ga. (Oct. '57) *MPD*

Guthrie, Robert H., Cons. Engr., Guthrie & Lyon, Waukesha, Wis. (Oct. '57) *RD*

Haber, J. P., Sr., Supt., Water Dept., Union City, Ind. (Oct. '57)

Haller, Ray Carl, Engr., L. I. Couch Co., Inc., 230 E. Ohio, Indianapolis, Ind. (Oct. '57) *RP*

Hardy, Bruce Allan, Engr., Horner & Shifrin, 803 Shell Bldg., St. Louis, Mo. (Oct. '57) *PD*

Hawkins, Kenneth H., Pump Salesman, Harry Alter & Sons, 514 S. Howell St., Davenport, Iowa (Oct. '57) *R*

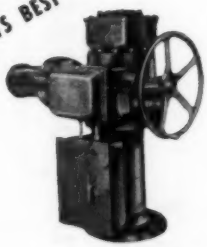
Heacox, Roland E., Chief Water Plant Oper., Bureau of Water, City Hall, Troy, N.Y. (Oct. '57)

Hill, Dale G., Accountant, Water Dept., Estes Park, Colo. (Oct. '57) *MR*

(*Continued on page 106 P&R*)

VALVE ACTUATION

ENGINEERING AT ITS BEST



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MOTOR OPERATED VALVE

Power actuation is available as a complete carefully engineered unit. Actuation may be by electric motor, air motor, or air or fluid cylinder type motivation. The power unit is compact and self contained, with sturdy supports which attach to the top of any Ludlow Valve.

Manual operation is provided for all electric and air motor operated valves. Our engineers will be glad to help you lay out a plan based on the many years of Ludlow experience in power actuation systems of all kinds for all purposes.

"NO POSSIBLE DIFFERENCE IN FIRST COST CAN OVERBALANCE THE PERPETUAL ECONOMY OF QUALITY."

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CYLINDER OPERATED VALVE

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Since 1861 THE LUDLOW VALVE MANUFACTURING CO. Troy, N. Y.

Forests Protected...

but how about our most precious possession...water?

You'll save water—increase the system income—with Badger Meters

Forest conservation costs millions — and it's worth it. But the millions of *wasted gallons* of increasingly scarce water *could* cost the future of entire communities. Yet one basic step—replacing flat rates with Badger Meters

water *could* cost the future of entire communities. Yet one basic step—replacing flat rates with Badger Meters

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Badger Meters have an unsurpassed record for low maintenance cost: ruggedly built of finest copper alloy. Control adjustment is simple. Working parts are few and standardized for easy, inexpensive replacement if ever needed.

By thus installing the finest meters available—Badger Meters—you put the department on an efficient, good-business basis, while saving vital water supplies through fair-share, fair-pay metering. Act now! Write for literature or to arrange a helpful consultation with a Badger Meter representative.

Outstanding disc, turbine and compound meters—⅝" through 12" —precision-engineered for lasting service.

Water is vital

Badger Meters have conserved it better for over 50 years.

Badger Water Meters

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Milwaukee 45, Wisconsin • *OFFICES IN PRINCIPAL CITIES*

(Continued from page 102 P&R)

Hollaman, Richard Buchanan, Public Utility Map Director, Sanborn Map Co., 10 Cedar St., New York 5, N.Y. (Oct. '57) *D*

Hollifield, Elige Jim, Sr., Pres., Hollifield Water Works Machinery Co., Inc., 2612 Midway St., Shreveport, La. (Oct. '57) *D*

Holmes, John W., Sales Engr., Byron Jackson Div., Borg Warner Corp., 407 S. Dearborn, Chicago 5, Ill. (Oct. '57) *R*

Hornback, Russell L., Contractor, Montrello, Ind. (Oct. '57) *D*

Horton, Morris C.; *see* Texas Fire Prevention & Eng. Bureau

Horwitz, Morris M., Salesman, 3718 N. Pine Grove Ave., Chicago 13, Ill. (Oct. '57) *P*

Hufft, Raymond J., Jr., Chief Engr., Hemco Engrs., 414 Falls Bldg., Memphis, Tenn. (Oct. '57) *MRPD*

Hurlbutt, Fred; *see* Garberville Water Co., Inc.

Jackson, Frederick Neil, City Mgr., City Hall, Alpena, Mich. (Oct. '57)

Jennings, Charles H., Gen. Engr., Sewer Operation Branch, Dist. San. Eng., 2nd & N Sts., S.E., Washington, D. C. (Oct. '57) *MR*

Jester, Carl Franklin, Jr., Asst. City Engr., Fredericksburg, Va. (Oct. '57) *MPD*

Johnson, Charles R., Sales Repr., Victaulic Co. of America, 292 Canoler St., N.E., Altanta 7, Ga. (Oct. '57)

Johnson, Harry M., 1200 W. 3rd St., Anaconda, Mont. (Oct. '57)

Johnson, Herbert E., Engr., Jensen & Johnson, 108 Court St., Elkhorn, Wis. (Oct. '57)

Johnson, James William, Mgr., Munic. Utilities Bd., Box 30, Albertville, Ala. (Oct. '57) *MPD*

Jones, Wallace W., Supt., Munic. Water Works, Box 27, Brooklyn, Ind. (Oct. '57) *M*

Jordan, Earl, Water Supt., Water Dept., Wolcottville, Ind. (Oct. '57)

Kessler, The K., Co., Inc., J. P. Beatty, Pres., 410 S. Front St., Fremont, Ohio (Assoc. M. Oct. '57)

Klecker, Edward J., Business Mgr., Bd. of Water Comrs., 2510 Pontiac St., Denver 7, Colo. (Oct. '57)

Knepper, Keith L., Supt., Light & Water, Walkerton, Ind. (Oct. '57)

Larrick, Charles L.; *see* City of Escondido (Calif.)

Lastovica, John F., Field Engr., Fairbanks Morse & Co., 2017 Dean, Des Moines, Iowa (Oct. '57) *D*

Leavell, Manley B., Repr., Hersey Mfg. Co., Dedham, Mass. (Oct. '57)

Legakes, Peter J., City Clerk, Box 668, Woodlake, Calif. (Oct. '57) *MD*

Lichty, Donald Sherwood, Engr., Bureau of Water, Allentown, Pa. (Oct. '57) *RD*

Liebler, Newell J., Sales Repr., Johns-Manville Sales Corp., 220 Delaware Ave., Buffalo 2, N.Y. (Oct. '57) *D*

Listebarger, Isaac G., Sales Engr., Rockwell Mfg. Co., 390 N. Lexington Ave., Pittsburgh 8, Pa. (Oct. '57)

Livingston, Walter, Mgr., Hoosier Water Co., Inc., Spencer, Ind. (Oct. '57) *MPD*

Logsdon, Horace T., Supt., Water Works, Fort Knox, Ky. (Oct. '57) *MRP*

Logsdon, Marvin L., Supt., Hardin County Water Dist. 1, 308 N. Wilson Ave., Radcliff, Ky. (Oct. '57) *M*

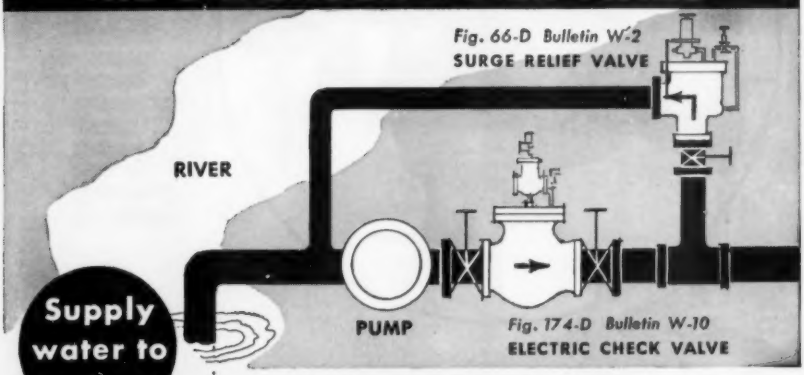
Long, Merle J., Salesman, Kennedy Valve Mfg. Co., 3650 Lesley Ave., Indianapolis, Ind. (Oct. '57) *PD*

Lusk, George K., Supt. of Highways, Bldg. Dept., & Water Works, 3235 Chili Ave., Churchville, N.Y. (Oct. '57) *MRPD*

Lynch, Vernon E., Dorr-Oliver, Inc., 942 Merchandise Mart, Chicago, Ill. (Oct. '57) *P*

(Continued on page 108 P&R)

THE G-A SHOCK-TAMER TWINS



Supply water to city

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The G-A Cushioned Surge Relief Valve protects water lines against excessive surges in the system by automatically opening when the inlet pressure exceeds a predetermined setting.

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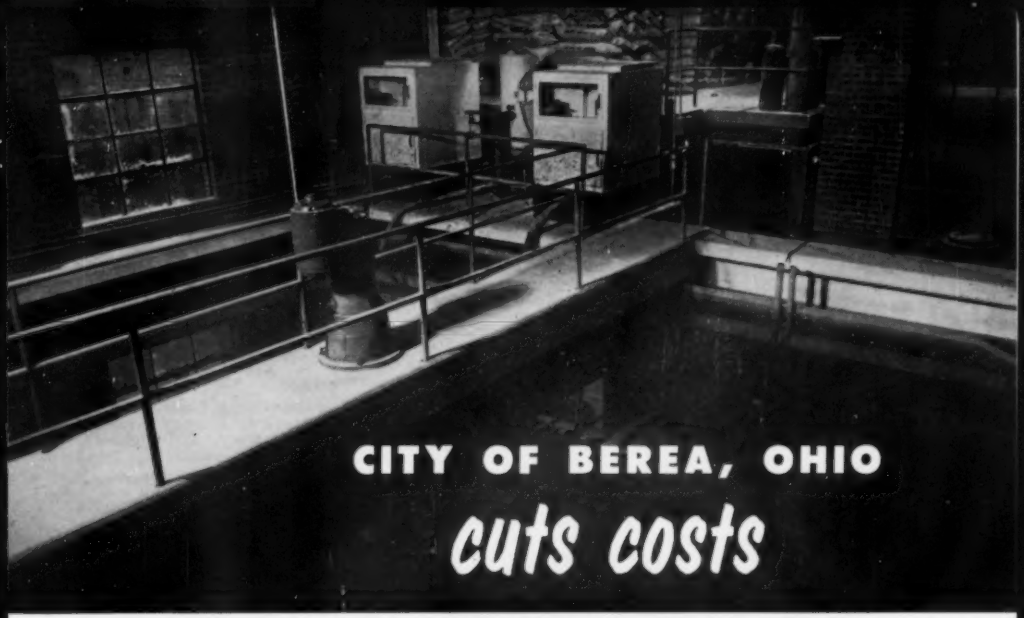

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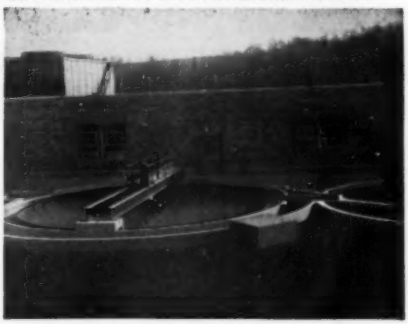

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(Continued from page 106 P&R)

MacWhinney, Sedgwick Rusling, Salesman, Keasbey & Mattison Co., Ambler, Pa. (Oct. '57) *D*

Maddox, Glenn M., Const. Supt., Water Dept., 2515 Elk St., Lafayette, Ind. (Oct. '57)

Madigan, James A., Pumper, Irrigation Dist., 738 Magnolia Ave., Beaumont, Calif. (Oct. '57) *PD*

Malan, O. J., Supt., Brown County State Park, Nashville, Ind. (Oct. '57) *MRPD*

Mang, O. K. C.; *see* Buffalo Pound Water Admin. Bd.

Mankin, Charles S., Comr., City Hall, Fort Smith, Ark. (Oct. '57) *MP*

Marlin, Hanley, Supt., Water Dept., 426 W. 1st St., Greensburg, Ind. (Oct. '57) *RPD*

Massara, Bernard J., Supt., Water Dept., 12th St., Hammonton, N.J. (Oct. '57) *MD*

McClure, Harold R., Civ. Engr., McClure Eng. Co., 2360 W. Dorothy Lane, Dayton, Ohio (Oct. '57) *P*

McCollum, Marvin P.; *see* California Brass Mfg. Co.

Meehan, Daniel W., Sr., Gen. Foreman, Water Works, 2414 Clara Ave., Fort Wayne, Ind. (Oct. '57) *M*

Meyer, Chris W., Supt., Water Dept., New Haven, Ind. (Oct. '57)

Miller, Henry E., Jr., Sales Repr., Hays Mfg. Co., Box 2121, Springfield, Mo. (Oct. '57)

Milner, Andrew M., Mayor, City Hall, Kendallville, Ind. (Oct. '57) *M*

Mount Pleasant Light & Water, G. W. Wright, City Mgr., W. Monroe, Mount Pleasant, Iowa (Munic. Sv. Sub. Oct. '57) *MD*

Nelson, Grant E., Sales Repr., Eddy Valve Co., Waterford, N.Y. (Oct. '57) *D*

Nelson, Leonard E., Cons. Engr., 7509—1st Ave., S., Minneapolis 23, Minn. (Oct. '57) *RD*

Newman, J. Leonard, Accountant Suffolk County Water Authority, 140 Orinoco Dr., Brightwaters, N.Y. (Oct. '57) *M*

Nielsen, Norman Stanley, Civ. Engr., Hackensack Water Co., 4100 Park Ave., Weehawken, N.J. (Oct. '57) *MR*

Noll, W. J., Jr., Regional Sales Repr., Adams Pipe Repair Products, Box 550, Columbia, Pa. (Oct. '57) *D*

Northington, Charles W., Asst. San. Engr., Bureau of Sanitation, State Health Dept., Montgomery, Ala. (Oct. '57) *P*

Oakland County Dept. of Public Works, R. J. Alexander, Deputy Director, 550 S. Telegraph Rd., Pontiac, Mich. (Munic. Sv. Sub. Oct. '57) *MRD*

O'Brien, Walter, Salesman, Ulrich Chem. Inc., 2640 W. Minnesota, Indianapolis 21, Ind. (Oct. '57)

Pearce, Cecil Edward, Civ. Engr., Ebasco Services, Inc., 2 Rector St., New York 6, N.Y. (Oct '57) *RD*

Philadelphia Gear Works, Inc., Martin C. Donze, Vice-Pres., G St. below Erie A., Philadelphia 34, Pa. (Assoc. M. Oct. '57)

Pillow, Raymond Eugene, Mgr., Water Dept., 124 Kirk Ave., S.W., Roanoke, Va. (Oct. '57) *MR*

Pounds, T. E.; *see* The Dow Chem. Co., Louisian Div.

Przybysz, Eugene S., Assoc. Chem. Engr., Armour Research Foundation, 3131 S. State St., Chicago, Ill. (Oct. '57) *P*

Rhodes, M. M., Chief Chemist, Standard Oil Co. of California, Western Operations, Inc., Box 97, El Segundo, Calif. (Oct. '57) *RP*

Richards, Ernest, Supt., Water Works, Edinburg, Ind. (Oct. '57) *MP*

(Continued on page 110 P&R)

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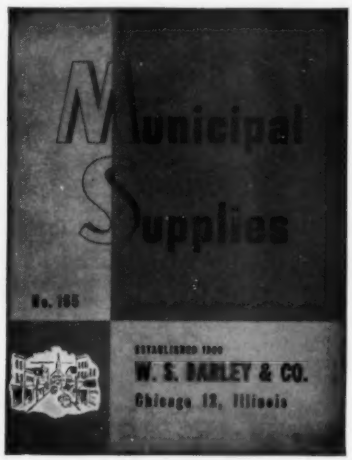

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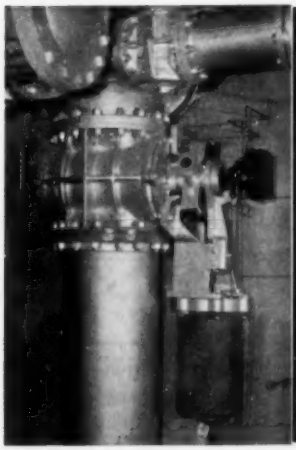

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(Continued from page 108 P&R)

Ring, Chester A., Asst. Distr. Engr., American Water Works Service Co., Inc., 3 Penn Center Plaza, Philadelphia 2, Pa. (Oct. '57) *MD*

Ritter, Anderson B., Asst. Director, Eng. Div., State Health Dept., Box 630, New Orleans 7, La. (Oct. '57) *RPD*

Robertson, William B., Comr., Water, Sewer & Light, Aurora, Ill. (Oct. '57) *M*

Rockland County Dept. of Health, G. Richard Sutherland, Director, Div. of Environmental Sanitation, New York, N.Y. (Corp. M. Oct. '57) *RP*

Rogers, Algie D., Purchasing Agent, Water Dept., Marion, Ind. (Oct. '57)

Ross, Edward Noble, Plant Engr., Lee Paper Co., Vicksburg, Mich. (Oct. '57) *P*

Roth, Russell G., Supt., Public Works, Plainfield, Ind. (Oct. '57) *MRPD*

Ruby, Kenneth W., Chemist, Water Dept., City Hall, Oskaloosa, Iowa (Oct. '57) *P*

Russell, J. Bernard; *see* Creston City (Iowa) Water Works

Saunders, Scott P., Sales Engr., Penn Instruments Div., Burgess-Manning Co., 4110 Haverford Ave., Philadelphia, Pa. (Oct. '57) *PD*

Schmidt, Victor B., Jr., Supt. of Dist., Water Dept., Box 1160, Austin, Tex. (Oct. '57)

Schrock, Paul Richard, Salesman, Harco Corp., Box 7026, Cleveland 28, Ohio (Oct. '57)

Sears, Earl, Supt., Water Works, Greenfield, Ind. (Oct. '57) *D*

Sefranka, Ray E., Engr., State Flood Control & Water Resources Com., 1330 W. Michigan St., Indianapolis, Ind. (Oct. '57) *R*

Shepper, Harbin, Supt., Munic. Water Works, Donnellson, Iowa (Oct. '57) *MRPD*

Siggins, Donald B., Supt., Water Works, Mount Vernon, Iowa (Oct. '57) *MRD*

Silvasi, Anthony Albert, Chemist, Water Dept., 1638 Davis Ave., Whiting, Ind. (Oct. '57)

Sinkinson, George Kenneth, Branch Mgr., The Ludlow Valve Co., Inc., 11 W. 42nd St., New York 36, N.Y. (Oct. '57)

Skotzke, John, Field Foreman, Ecorse Twp., Wyandotte, Mich. (Oct. '57) *D*

Smith, Raymond Gilbert, Plant Oper., Booneville Water Co., Booneville, Ark. (Oct. '57) *PD*

Smith, Talbert E., Jr., Application Engr., Burford, Hall & Smith, Box 1339, Atlanta 1, Ga. (Oct. '57) *D*

Spiniello, Luke C.; *see* Spiniello Const. Co.

Spiniello Const. Co., Luke C. Spiniello, Pres., 249 Wallace St., Orange, N.J. (Assoc. M. Oct. '57)

Standridge, James E., Gen. Mgr., Water Dept., Box 189, Anniston, Ala. (Oct. '57) *MD*

Stanley, James Gordon, Sales Engr., Price Brothers Co., 1932 E. Monument Ave., Dayton, Ohio (Oct. '57) *D*

Steffen, John A., Water Supt., 513 N. Main St., Fortville, Ind. (Oct. '57)

Stewart, Melbourne George, Engr., Dept. of Water Supply, Detroit, Mich. (Oct. '57) *MD*

Stichler, Theodore, Utilities Supt., Light & Water Dept., Argos, Ind. (Oct. '57)

Strachan, Michael, Field Engr., The Pitometer Assocs., Inc., 50 Church St., New York 7, N.Y. (Oct. '57) *RD*

Suedkamp, John, Chem. Eng., Water Dept., Hamilton, Ohio (Oct. '57) *MP*

Sullivan, Arthur Eugene, Clerk, Robert W. Sullivan, Inc., McCarron & Sullivan Assoc., 45 Newbury St., Boston 16, Mass. (Oct. '57) *PD*

Sutherland, G. Richard; *see* Rockland County (N.Y.) Dept. of Health

Sutherlin, City of, William H. Findley, Supt. of Public Works, Box 632, Sutherlin, Ore. (Munic. Sv. Sub. Oct. '57) *PD*

Tanner, Homer M., Tech. Service Engr., Ethyl Corp., Box 341, Baton Rouge 1, La. (Oct. '57) *RP*

Taylor, Malcolm E., Supt., Water Works, Galveston, Ind. (Oct. '57) *D*

Texas Fire Prevention & Eng. Bureau, Morris C. Horton, Asst. Chief Engr., 520 Mercantile Securities Bldg., Dallas 1, Tex. (Corp. M. Oct. '57) *MRD*

Thomas, Alan, Supt., Water Dept., City Hall, Millville, N.J. (Oct. '57)

Visking Co., Div. of Union Carbide Corp., Ray J. Whittington, Plant Chemist, Loudon Plant, Box 486, Loudon, Tenn. (Corp. M. Oct. '57) *P*

Wait, Merlin, Mgr., Munic. Elec. & Water Plant, Coon Rapids, Iowa (Oct. '57) *MRD*

Wasley, Henry Gerald, Asst. Mgr., American Cast Iron Pipe Co., Birmingham, Ala. (Oct. '57) *D*

Way, John H., Secy.-Treas., McCaffrey-Way Materials & Supply Co., Inc., Albuquerque, N.M. (Oct. '57) *RD*

Webster, Royal S. Walsh, Pres., Servicios Tarara S.A., Edif. Bacardi 215, Havana, Cuba (Oct. '57) *M*

Whittington, Ray J.; *see* Visking Co., Div. of Union Carbide Corp.

Williams, Charles T., Layne Northern Co., 227 W. Edwards Ave., Indianapolis, Ind. (Oct. '57)

Wilson, William, Supt., Water Works, Brownsburg, Ind. (Oct. '57) *MD*

Wiltsie, Ralph, Mayor, 115 S. Hart, Princeton, Ind. (Oct. '57)

Wright, G. W.; *see* Mount Pleasant (Iowa) Light & Water

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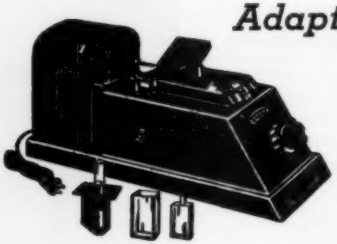

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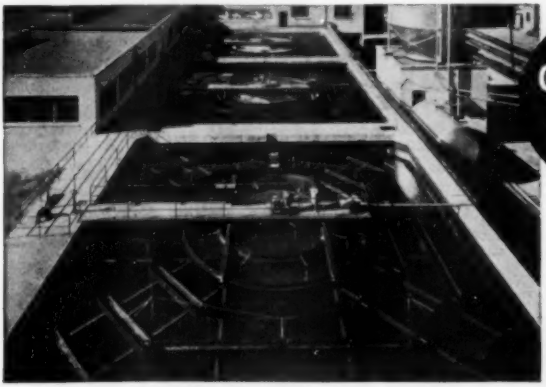

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Allis-Chalmers Mfg. Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Hydraulic Development Corp.
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Jos. G. Pollard Co., Inc.

Lime Slakers and Feeders:
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Omega Machine Co. (Div., B-I-F Industries, Inc.)
Permutit Co.
Wallace & Tiernan Inc.

Magnetic Dipping Needles:
W. S. Darley & Co.

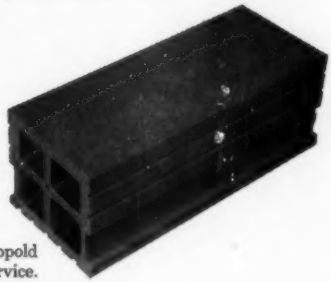
Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.

A GOOD COMBINATION

for better performance— lower operating costs...

LEOPOLD FILTER BOTTOMS



Designed to successfully meet all underdrain requirements

Made of de-aired fire clay—vitrified and salt glazed, the Leopold Filter Bottom is unequalled for dependable, economical service. The individual blocks resist corrosion, are not subject to tuberculation, and will last indefinitely. Too, they require only small sized gravel, do not need special supporting concrete members, and the Leopold design insures uniform wash distribution.

LEOPOLD Rubber Seated BUTTERFLY VALVES

Assure positive drop-tight shut-off easily, efficiently, economically.

In this design, the seat is of resilient Neoprene rubber or pure gum rubber, vulcanized around a steel ring insert, and held in place by a keeper ring. The steel ring, which is "continuous" to eliminate abnormal wearing, increases the firmness of the seat and assures longer service life.

Whether operated manually or by automatic controls, Leopold Butterfly Valves always provide a positive shut-off that's bubble-tight. Made in sizes 6" to 96".

Meet AWWA Specifications C504-55T

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F. B. LEOPOLD CO., INC.
ZELIENOPLE, PA.

COMPLETE WATER PURIFICATION AND FILTER PLANT EQUIPMENT • BUTTERFLY VALVES
FILTER OPERATING TABLES • MIXING EQUIPMENT • DRY CHEMICAL FEEDERS

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Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
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Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

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Burgess-Manning Co., Penn Instruments Div.
Foster Eng. Co.
Infilco Inc.
Simplex Valve & Meter Co.
Sparling Meter Co.

Meters, Industrial, Commercial:
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Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
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Meter Repair Parts
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Mixing Equipment:
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Pipe, Asbestos-Cement:
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Reed Mfg. Co.
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Pipe Jointing Materials; see Jointing Materials

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Pipe Vises:
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Carus Chemical Co.

Pressure Regulators:
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Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
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Pumps, Boiler Feed:
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DeLaval Steam Turbine Co.
Layne & Bowler Pump Co.
Worthington Corp.

Pumps, Centrifugal:
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American Well Works
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Chemical Feed:
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Milton Roy Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

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Layne & Bowler, Inc.
Layne & Bowler Pump Co.
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W. S. Rockwell Co.
Wallace & Tiernan Inc.

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Pumps, Hydraulic Booster:
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Pumps, Sewage:
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DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Sump:
DeLaval Steam Turbine Co.
Layne & Bowler Pump Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.
Layne & Bowler Pump Co.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Infilco Inc.
Simplex Valve & Meter Co.
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Reservoirs, Steel:
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Graver Tank & Mfg. Co.
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Pittsburgh-Des Moines Steel Co.
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Sand Expansion Gages; see Gages

Sleeves: see Clamps

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M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

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Graver Water Conditioning Co.
Permutit Co.

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American Agricultural Chemical Co.

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Calgon Co.

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Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

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Permutit Co.
Tennessee Corp.

Standpipes, Steel:
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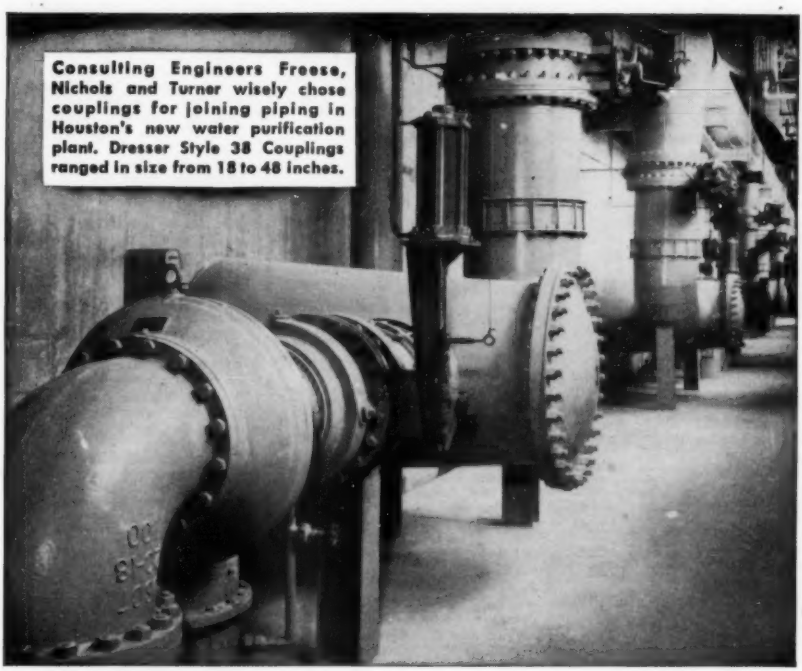
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.



Consulting Engineers Freese, Nichols and Turner wisely chose couplings for joining piping in Houston's new water purification plant. Dresser Style 38 Couplings ranged in size from 18 to 48 inches.

Houston solves piping problems for good

Steel pipe and Dresser Couplings provide flexible installation, easy accessibility

Houston's new water purification plant, a part of the San Jacinto River Water Project, integrates some of the latest developments in industrial design with time-proved principles of municipal water treatment.

The new plant reflects the wise use of steel pipe and mechanical couplings where weight, price and greater flexibility are important factors.

Consulting Engineers Freese, Nichols and Turner of Houston specified Dresser Couplings teamed with steel pipe "to provide for expansion and contraction of long runs of pipe, to provide for flexibility in the installation and possible future dismantling of large pipe assemblies, and to connect steel pipe to concrete hydraulic structures."

Whenever you join pipe—especially near valves or any type of mechanical installation—provide easier installation and permanence with safe, sure Dresser Couplings.

Regardless of vibration or expansion-contraction, the resilient gaskets in Dresser Couplings hold bottle-tight for life. This built-in flexibility, particularly important between rigid flanges, serves to prevent piping strain from reaching valve casings and working parts. Result: greater efficiency, longer life.

Installation with Dresser Couplings requires only a wrench, is fast and simple. You can forget time-consuming procedures because Dresser Couplings compensate for slight misalignments, facilitate installation of set, rigid equipment on piping. These couplings also permit easy entrance into lines for maintenance or repair of equipment.

No other method of pipe joining provides all these proved advantages. Make sure you have foolproof, leakproof Dresser Couplings on your next water, sewerage or industrial project. For complete information, call your local piping supply house or write Dresser Manufacturing Division, Bradford, Pa. Sales offices in: New York, Philadelphia, Chicago, S. San Francisco, Houston, Denver, Toronto and Calgary.

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Tapping Machines, Corp.:
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Graver Water Conditioning Co.
Industrial Chemical Sales Div.
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Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

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Wallace & Tiernan Inc.

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DeLaval Steam Turbine Co.

Turbines, Water:
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DeLaval Steam Turbine Co.

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Rensselaer Valve Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
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A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
W. S. Rockwell Co.
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Valves, Detector Check:
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Valves, Electrically Operated:
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Kennedy Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
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James B. Clow & Sons
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Ross Valve Mfg. Co., Inc.

Valves, Gate:
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Kennedy Valve Mfg. Co.
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Golden-Anderson Valve Specialty Co.
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Valves, Large Diameter:
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Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
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M & H Valve & Fittings Co.
Muller Co.
Henry Pratt Co.
Rensselaer Valve Co.
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A. P. Smith Mfg. Co.
S. Morgan Smith Co.
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Valves, Regulating:
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Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
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Valves, Swing Check:
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Chicago Bridge & Iron Co.
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Etablissements Degremont
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

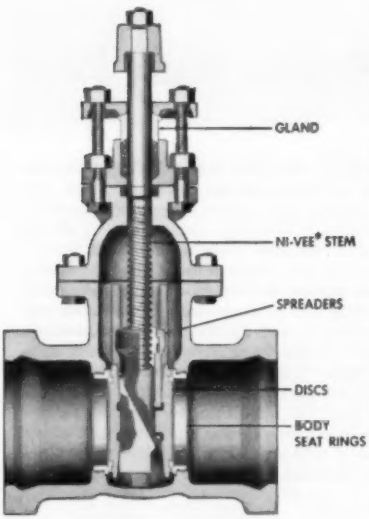
Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1957 AWWA Directory.

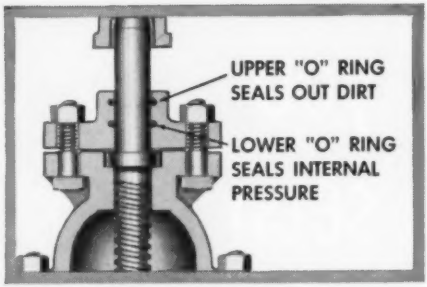
New CRANE A.W.W.A. Valves give you a wider selection

To meet special requirements, Crane now makes A.W.W.A. valves with two additional modifications. One is *all-bronze internal parts*. The other is double "O" ring stuffing boxes as an alternate to conventional stuffing box.

The basic design of Crane A.W.W.A. valves—with free-to-rotate disc assembly—has never been surpassed for ease of operation, positive seating, and low maintenance. With or without the new modifications, Crane A.W.W.A. valves are the most economical for any municipality.



No. 480-½-BD hub-end valve.



NOW—CRANE A.W.W.A. Valves with "O" Ring Stuffing Boxes

"O" ring stuffing boxes also available. Two Buna-N "O" ring seals are used. Lower ring seals in the internal pressure; upper ring is an external dirt seal and reserve pressure seal. Crane A.W.W.A. non-rising stem valves with "O" ring stuffing boxes are available with hub, flanged and mechanical joint ends. Also with ends for "Ring-tite" and "Fluid-tite" Asbestos-cement pipe. All in sizes from 2″ to 12″.

Crane's answer to corrosive water problems—all-bronze internal parts

Where required because of unusual water conditions, Crane A.W.W.A. valves with *all-bronze internal parts*—body rings, discs, upper and lower spreader, gland and "Ni-Vee"* Type A stem—are available. With hub, flanged and mechanical joint ends—in all sizes from 2″ to 12″.

For complete information about Crane A.W.W.A. valves, write your Crane Representative. Or send for Circular 2108.

*"Ni-Vee" is registered trade-mark of the International Nickel Co.

CRANE VALVES & FITTINGS

PIPE • PLUMBING • KITCHENS • HEATING • AIR CONDITIONING

Since 1855—Crane Co., General Offices: Chicago 5, Ill.
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The World's First Sealed Register Water Meter

Hermetically Sealed Register
Never Fogs—Always Easy To Read

All the register parts and reduction gearing are hermetically sealed in this stainless steel housing having a thick, heat treated glass window. Condensation, dust and corrosion are permanently excluded. A powerful magnetic drive eliminates the need for a stuffing box.

Everything about the Rockwell Sealed Register Water Meter makes history. Makes sense, too. It's the first water meter to operate successfully without a troublesome stuffing box. A simple, powerful magnetic coupling does this work—without friction, binds or leaks. The hermetically sealed register forever eliminates condensation problems that often make ordinary meter registers hard to read. Ends corrosion problems, too.

Even Rockwell has never made a more accurate meter. It requires less maintenance than any meter you have ever used. And it's tamperproof. The cost? No more than an ordinary meter—actually less than meters now fitted with special types of registers. Write for bulletin. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

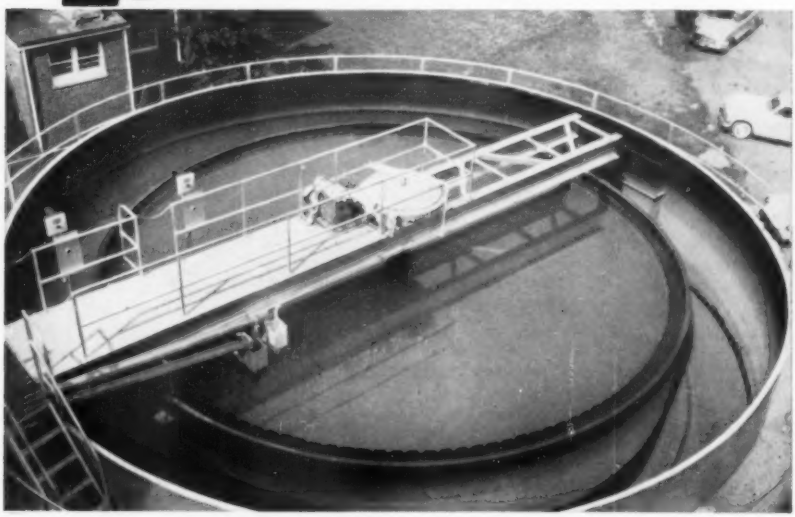
Rockwell Sealed Register Water Meter

With Powerful Magnetic Drive

The solution to this problem is always the same . . . but

Water Treatment Problems are different

No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.



Fountain City
TENNESSEE

PeriFilter System employs split filter for continuous operation

Close up of PeriFilter System taken while backwashing right side of filter. Left side of filter remains in operation.

Consulting Engineers: Polk, Powell and Hendon, Birmingham, Alabama.

Producing 1.0 MGD of finished water from limestone springs at Fountain City, this Dorrco PeriFilter System consists of a single 30′ dia. Hydro-Treator surrounded by an annular rapid sand filter. To maintain continuous operation, the filter is split by a partition plate and backwashed one half at a time. During backwashing, Hydro-Treator effluent overflows into the inner launder and is distributed to the opposite half of the filter. The results at Fountain City have been uniformly excellent with an average turbidity in the filtered water of less than 0.3 ppm.

For more information on the complete line of D-O equipment for the water works industry write for a copy of Bulletin No. 9041. Dorr-Oliver Incorporated, Stamford, Connecticut.

Hydro-Treator, PeriFilter, T.M. Reg. U. S. Pat. Off.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

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WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
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LEADITE

Trade Mark Registered U. S. Pat. Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking